

CHARACTERIZATION OF PARTICULATE EMISSIONS FROM GASOLINE-FUELED VEHICLES

**Final Report
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ABSTRACT

This two-phase program was designed to (1) increase our knowledge of particulate emission rates from gasoline-fueled vehicles representative of the modern fleet, (2) provide a characterization of the size distribution and chemical composition of these emissions, and (3) assess the effects of vehicle operating condition, driving cycle, and fuel type on particulate emission rates. Phase 1 examined the effects of three variables on particulate emissions and composition: driving cycle (Federal Test Procedure (FTP) vs. Unified Cycle (UC)), fuel effects (pre-1992 California average gasoline and California Phase 2 reformulated gasoline (RFG)), and vehicle technology (three-way catalyst (TWC) with multi-point fuel injection (MPFI), oxidation catalyst, and non-catalyst-equipped). Overall, driving cycle had the most significant effect on particulate emissions, with all vehicle technologies showing a statistically significant increase in particulate emissions on the UC over the FTP. This effect was largest on an absolute and relative basis for the oxidation and non-catalyst vehicles. The effect of fuel composition on particulate emissions was smaller than the effect of driving cycle and varied between vehicle technologies. The fuel effect was largest for the non-catalyst vehicle, with RFG producing lower particulate emissions than the pre-1992 fuel.

The scope of testing was broadened for Phase 2 to expand the database of particulate emissions over the UC for a larger and more representative fleet. The test matrix included vehicles in the following categories: 1955-1974 (1), 1975-1980 (4), 1981-1985 (7), and 1986+ (12). Unified Cycle particulate mass emission rates from 1986 and newer gasoline vehicles were generally low (<5 mg/mi) with modest increases in emission rates found for older model year and emission control technologies. Overall, the mass emission rates were comparable to those observed previously for FTP testing of larger vehicle fleets. Measurements of particulate size distributions and chemical composition were also included the test matrix for Phases 1 and 2.

EXECUTIVE SUMMARY

This program was designed to increase our knowledge of particulate emission rates from gasoline-fueled vehicles representative of the modern fleet, provide a characterization of the size distribution and chemical composition of these emissions, and assess the effects of vehicle operating condition, driving cycle, and fuel type on particulate emission rates. The program was divided into two phases. Phase 1 was a baseline data gathering effort to examine the effects of driving cycle and fuel composition on particulate emissions for three different technology gasoline vehicles. The test matrix included three different technology vehicles (three-way catalyst (TWC) with multi-point fuel injection (MPFI), oxidation catalyst (OC), and non-catalyst equipped), two driving cycles (Federal Test Procedure (FTP) and Unified Cycle (UC)), and two fuels (pre-1992 California average gasoline and California Phase 2 gasoline (RFG)).

The results of Phase 1 were used to develop the protocol for Phase 2, in which the objective was to develop emissions factors for the UC. The scope of testing for Phase 2 was broadened to include a larger and more representative fleet. The test matrix included vehicles in the following categories 1955-1974 (1), 1975-1980 (4), 1981-1985 (7), and 1986+ (12). All testing in Phase 2 was conducted over the UC to provide a baseline of particulate data for model development using this cycle. Measurements of particulate size distributions and chemical composition were also included the test matrix for Phases 1 and 2. The results and conclusions of both Phases 1 and 2 are summarized below.

Phase 1

- The vehicle matrix for Phase 1 included three vehicles representing three distinctly different technologies. These vehicles are described in Table ES-1.

Table ES- 1. Descriptions of Test Vehicles for Phase 1

Model Year	1990	1981	1967
Manufacturer	Ford Tempo GL	Datsun 310	Ford Mustang
Fuel Delivery System	Multi-point fuel injection	Carburetor	Carburetor
Emission Control System	Three-way Catalyst	Oxidation Catalyst	Non-Catalyst

- The weighted FTP and UC discussion are summarized in Table ES-2. It should be noted that the conclusions regarding the emission results are based on the analyses of all available data, including results of replicate bag 2 measurements which are not included in Table ES-2. It is also important to note that the small sample size for Phase 1 precludes generalizations to vehicles beyond the single vehicle tested for each model year/technology group.

Table ES-2. Summary of FTP and Unified Cycle Weighted Emissions for Phase 1

Cycle/Fuel	1990 Ford Tempo					1981 Datsun 310					1967 Ford Mustang				
	THC	NMHC	NO _x	CO	Parts.	THC	NMHC	NO _x	CO	Parts.	THC	NMHC	NO _x	CO	Parts.
	g/mi	g/mi	g/mi	g/m	Mg/mi	g/mi	g/mi	g/mi	mg/m	g/mi	g/mi	g/mi	g/mi	mg/m	g/mi
FTP/RFG	0.28	0.20	0.31	5.92	1.27	0.43	0.35	0.94	6.17	3.68	3.72	3.43	1.02	93.13	10.25
FTP/Pre-1992	0.33	0.27	0.32	6.39	1.76	0.51	0.42	1.10	7.82	5.61	4.09	3.77	0.92	111.44	15.66
UC/RFG	0.21	0.16	0.50	5.08	3.03	0.54	0.42	1.75	7.61	18.56	4.67	4.27	1.47	134.54	33.52
UC/Pre-1992	0.21	0.17	0.54	5.53	2.33	0.66	0.55	1.90	8.11	15.08	5.13	4.68	1.30	151.45	62.37

- All vehicle technologies showed a statistically significant effect of higher particulate emissions on the UC than the FTP. This effect was largest in an absolute and relative basis for the oxidation and non-catalyst technologies, as shown in Table ES-2.
- The effects of driving cycle on gaseous emissions are generally less than the effect on particulate emissions. Consistent and statistically significant trends of increased gaseous emissions over the UC were observed for the oxidation catalyst and non-catalyst vehicle, but not for the TWC vehicle.
- The effect of fuel composition on particulate emissions was smaller than the driving cycle effect and varied between vehicle technologies.
- For the non-catalyst vehicle, the Phase 2 gasoline produced lower overall particulate emissions than the pre-1992 fuel.
- For the oxidation catalyst vehicle, the particulate emissions results varied for different phases, with higher particulate emissions for pre-1992 gasoline for bag 1 and lower for bag 2. The result for bag 2 may be attributable to preconditioning effects, however.
- For the TWC vehicle, fuel differences had essentially no effect on particulate emissions with the possible exception of bag 1 emissions.
- RFG resulted in a trend of lower THC, CO, and NO_x emissions for the oxidation catalyst vehicle and lower THC and CO emissions for the non-catalyst vehicle. The effects on gaseous emissions of TWC vehicle were varied and may have been affected by vehicle repeatability.
- The chemical breakdowns show that elemental and organic carbon are the primary constituents of gasoline particulates. Inorganic species comprise a smaller portion of the total particulate and include sulfate, elemental Si and S.
- Sulfate and other ions make a relatively small contribution to the total particulate.
- Lower percentages of organic carbon relative to elemental carbon are observed for the catalyst-equipped Ford Tempo and Datsun compared with the non-catalyst Ford Mustang.
- The overall mass emission rates for inorganic species are relatively consistent from vehicle to vehicle. On a percentage basis, inorganic species compose a larger fraction of the total particulate matter for the catalyst-equipped vehicles with lower mass emission rates.
- Overall, the particulate composition was not strongly fuel-dependent, although there is some evidence that fuel may affect the organic fraction of the particulate. In particular, for all three vehicles, organic carbon represented a larger fraction of the total particulate carbon for tests conducted on RFG compared with those conducted on pre-1992 gasoline. This result was only statistically significant for the Datsun, however. The effect of fuel on the particulate emissions of ions and elements was relatively minor.
- Driving cycle did not have a significant impact on the organic to elemental fractions of the

particulate. The combined emissions of all ions and elements were higher for the UC than the FTP for all three test vehicles. This is consistent with the overall higher particulate emissions observed for the more aggressive UC.

- Although some differences were observed between different bags for elemental and organic carbon for different vehicles and cycles, most of these differences were not statistically significant. Combined emissions of all elements and ions were higher for the Datsun for bag 2 of the UC compared with bags 1 and 3. This can probably be attributed to the more aggressive nature of bag 2 of the UC.
- A Micro-Orifice Uniform Deposit Impactor was used to obtain particulate size distributions. The MOUDI was configured using impaction substrates corresponding to >18, 10, 3.2, 1.8, and 1.0 μm aerodynamic diameter and an after filter to determine the total mass below 10.0, 2.5, and 1.0 μm aerodynamic diameter. The size distributions for the Datsun 310 and Ford Mustang were consistent with the results of previous studies with approximately 80 to 95% of the particulates below 1.0 μm in diameter. For the Ford Tempo, a considerably larger fraction of the particulate mass was greater than 1.0 μm in diameter. This could be due to sources of larger particulates, such as retrained particulates, which may make a greater contribution to the total particulate as engine out emissions decrease or for more aggressive cycles.

Table ES-3. Particulate Size Distributions for MOUDI Tests

Cycle	Fuel	Mass Percentage		
		<10 μm	<2.5 μm	<1.0 μm
1990 Ford Tempo				
FTP	Calif. Phase 2	80.8%	68.6%	55.9%
FTP	Calif. Pre-1992	83.8%	66.7%	55.4%
Unified Cycle	Calif. Phase 2	77.4%	57.6%	49.5%
Unified Cycle	Calif. Pre-1992	80.7%	52.6%	34.6%
1981 Datsun 310				
FTP	Calif. Phase 2	95.7%	90.0%	89.6%
FTP	Calif. Pre-1992	94.9%	90.1%	79.4%
Unified Cycle	Calif. Phase 2	97.2%	91.0%	84.3%
Unified Cycle	Calif. Pre-1992	97.5%	92.3%	85.0%
1967 Ford Mustang				
FTP	Calif. Phase 2	91.5%	85.5%	80.3%
FTP	Calif. Pre-1992	96.8%	92.7%	89.6%
Unified Cycle	Calif. Phase 2	96.3%	91.6%	87.8%
Unified Cycle	Calif. Pre-1992	98.3%	96.5%	93.8%

Phase 2

- The scope of testing was broadened in Phase 2 to include a total of 24 vehicles. The target test matrix is presented in Table ES-4. All vehicles were tested over the Unified Cycle in RFG for Phase 2.

Table ES-4. Target Vehicle Test Matrix for Phase 2

Manufacturer Breakdown		
Model Years	Domestic	Foreign
1955-1974	1	0
1975-1980	2	2
1981-1985	4	3
1986+	6	6

Technology Breakdown		
Model Years	Technology Type	
1955-1974	non-catalyst	1
1975-1980	Oxidation catalyst	4
1981-1985	Throttle-body/Carburetor/TWC	5
	Multi-point fuel injection/TWC	2
1986+	Throttle-body/Carburetor/TWC	2
	Multi-point fuel injection/TWC	10

TWC = 3-way catalyst

- UC particulate mass emission rates from newer 1986+ model year gasoline vehicles are low (< 5 mg/mi) with modest increases in emission rates found for older model year and emission control technologies. These results are presented in Table ES-5. Overall, the mass emission rates were comparable to those observed previously for FTP testing of larger vehicle fleets.

Table ES-5. Unified Cycle Weighted Particulate Emission Rates for Phase 2

Model Year	# of vehicles	Ave. PM mg/mi	Median mg/mi	Max. PM mg/mi	Min. PM mg/mi
1955-1975	1	67.0			
1975-1980	4	47.1	27.4	126.2	7.4
1981-1985	7	20.0	22.7	35.3	5.2
1986+	12	4.5	2.9	19.3	0.7

- Particulate emissions for Bag 1 of the UC are the highest. Particulate emissions for Bags 2 and 3 are comparable to each other. Average emissions for each model year category are presented by bag in Table ES-6.

Table ES-6. Phase 2 Unified Cycle Particulate Matter Emission Results by Bag

	# of Vehicles	Bag 1	Bag 2	Bag 3
		Mg/mi	mg/mi	mg/mi
1955-1975	1	309.3	32.7	21.1
1975-1980	4	85.1	44.0	67.8
1981-1985	7	57.2	16.4	10.6
1986+	12	21.0	3.2	1.8

Note: averages are for all vehicles in category

- Vehicle conditioning appears to be an important issue with regard to measuring particulate emissions on aggressive cycles such as the UC. Of the 24 vehicles tested in Phase 2, 16 had particulate emissions that were lower by 25% or more on the replicate tests than in the bag 2 collected for the initial test(s). These results are presented in Table ES-7. These data indicate that vehicle preconditioning and repeatability are important issues to address and merit further investigation in future work.

Table ES-7. Comparison of Average UC Bag 2 Replicate Test Results by Model Year Category

Model Year	# of vehicles	Vehicles decreasing by >25% ^a	Average Bag 2 PM Emissions From first test(s)	Average Bag 2 PM Emissions From replicate test(s)	% Difference
1955-1975	1	1	56.1 mg/mi	20.9 mg/mi	-62.7%
1975-1980	4	3	43.3 mg/mi	42.1 mg/mi	-2.8%
1981-1985	7	5	18.5 mg/mi	15.3 mg/mi	-17.2%
1986+	12	7	3.7 mg/mi	3.0 mg/mi	-20.7%

^aNumber of vehicles where the particulate emissions for the replicate test were reduced by greater than 25% from the initial test

- Average NMHC, CO and NO_x emissions rates all increase with increasing vehicle age, consistent with the particulate emission results. Average UC weighted emissions for NMHC, CO, and NO_x by model year category are presented in Table ES-8.

Table ES-8. Unified Cycle Weighted Gaseous Emission Rates for Phase 2

Model Year	# of vehicles	Ave. NMHC g/mi	Ave. CO g/mi	Ave. NO _x g/mi
1955-1975	1	1.998	62.537	4.935
1975-1980	4	1.339	32.582	2.428
1981-1985	7	1.164	33.842	1.344
1986+	12	0.472	11.079	0.736

- Chemical analyses were conducted on 10 of the 24 vehicles tested in Phase 2. A list of vehicles tested is presented in Table ES-9.

Table ES-9. Vehicle List for Phase 2 Chemical Analysis

	Make, Model, and Model Year	Technology
1	1975-1980 Domestic	OC
2	1975-1980 Foreign	OC
3	1981-1985 Domestic	TBI/ TWC
4	1981-1985 Foreign	Carburetor/TWC
	1986+	
5	1986+ Domestic	TBI/TWC
6-7	1986+ Domestic	MPFI/TWC
8-10	1986+ Foreign	MPFI/TWC

TBI = throttle-body injection; MPFI = multi-point fuel injection
TWC = 3-way catalyst; OC = oxidation catalyst

- The average chemical mass emission rates for the 10 vehicles sampled are presented in Table ES-10. These data include only detected species. A more complete list of species is provided in the body of the report.

Table ES-10. Statistics for PM Emission Rates of Chemical Species (mg/mi)

	Ave	St Dev	Stand. Uncert.	Max.	Min
Organic Carbon	9.71	21.77	0.98	66.13	0.09
Elemental Carbon	1.92	2.33	0.18	7.17	0.27
Total Carbon	11.63	23.23	1.14	70.39	0.52
NO ₃ ⁻	0.01	0.01	0.02	0.04	0.00
SO ₄ ²⁻	0.10	0.14	0.02	0.46	0.02
Cl ⁻	0.00	0.02	0.02	0.04	-0.01
NH ₄ ⁺	0.01	0.01	0.02	0.03	-0.01
Mg	0.05	0.13	0.01	0.39	-0.01
Al	0.00	0.00	0.01	0.01	0.00
Si	0.29	0.28	0.03	0.84	0.01
P	0.08	0.16	0.01	0.51	0.00
S	0.06	0.11	0.01	0.34	0.01
Cl	0.02	0.02	0.00	0.05	0.00
Ca	0.14	0.30	0.01	0.94	0.01
Cr	0.00	0.00	0.00	0.01	0.00
Mn	0.00	0.00	0.00	0.01	0.00
Fe	0.24	0.42	0.02	1.35	0.01
Cu	0.01	0.01	0.00	0.05	0.00
Zn	0.14	0.32	0.01	0.99	0.01
Mo	0.00	0.00	0.00	0.01	0.00
Ba	0.01	0.02	0.04	0.04	0.00
La	-0.03	0.01	0.05	0.01	-0.04
Pb	0.01	0.02	0.00	0.05	0.00

Note: Bold numbers indicate averages that are at least twice the average uncertainty

- As shown in Table ES-10, elemental and organic carbon were the primary constituents for the particulates.
- Inorganic species, including ions and trace elements, composed an average of 12.9% of the total mass. The most prominent chemical species were Fe, Si, SO₄²⁻, Ca, and Zn.
- On a vehicle average basis, organic carbon represented a larger fraction of the total carbon than elemental carbon. The contribution of organic carbon was generally larger for the older, higher emitting vehicles. The elemental and organic fractions of the total carbon mass for each vehicle are presented in Table ES-11, along with total PM emission rate.

Table ES-11. Elemental and Organic Carbon Fractions for Gasoline Vehicles (% of Total Particulate Carbon)

			Total PM (mg/mi)	Organic Carbon	Elemental Carbon
1994	Dodge	Shadow	1.84	45.2%	54.8%
1990	Nissan	Sentra	5.52	30.7%	69.3%
1990	Ford	Tempo	3.21	63.8%	36.2%
1989	Toyota	Celica	1.46	17.9%	82.1%
1987	Acura	Integra	4.29	70.6%	29.4%
1987	Buick	Park Avenue	3.05	37.2%	62.8%
1985	Oldsmobile	Cutlass	5.18	75.3%	24.7%
1984	Mazda	626	25.32	72.4%	27.6%
1980	Honda	Prelude	8.92	79.8%	20.2%
1979	Plymouth	Horizon	97.69	93.9%	6.1%

- The contribution of organic carbon needs to be added to the ARB's source profiles for gasoline vehicles. The levels of particulate sulfate in this study are substantially less than those currently being used in the ARB's source profile, however.
- The percentages of total particulate mass emissions below 10.0, 2.5 and 1.0 μm aerodynamic diameter are presented in Table ES-12. These results show that the majority of the particulate is below 1.0 μm in diameter, consistent with the results from previous studies.

Table ES-12. Percent of Particulate Mass less than 10.0, 2.5, and 1.0 μm

Category	Percent Less Than		
	10 μm	2.5 μm	1.0 μm
1986+	96.0%	91.3%	84.6%
1981-1985	95.4%	89.4%	82.5%
1975-1980	97.7%	94.1%	88.8%
Pre-1975	96.1%	89.2%	82.6%

- Total PAH emissions rates averaged 1,527 $\mu\text{g}/\text{mi}$ for the gasoline vehicles, with a range from 63 to 7,386 $\mu\text{g}/\text{mi}$. The distribution of PAHs was similar to that reported previously, with naphthalene, methylnaphthalene, and dimethylnaphthalene being primary constituents. Other PAHs identified include acenaphthylene, phenanthrene, methylfluorene, fluorene, and pyrene.
- Hopane or sterane compounds were, for the most part, not measured at levels above twice the average analytical uncertainty. Since hopanes and steranes are primarily oil tracers, this indicates that excessive oil burning did not make a significant contribution to the particulate composition for any of the 10 vehicles analyzed. This result also suggests that hopanes and steranes are of limited use in developing source profiles for gasoline vehicles, since their emissions are significant for only a portion of the gasoline fleet vehicles.

Recommendations

Based on the results of this study, the following recommendations are made:

- Further studies comparing particulate emissions for the FTP and more aggressive driving cycles such as the UC and US06 are needed. This work should include a larger and more representative sample of vehicles, and include light-duty trucks.
- More extensive studies of the effects of driving cycle and vehicle operating mode should be conducted using real-time particulate sampling techniques such as a condensation particle counter or spectrophone.
- Additional studies are needed to develop and assess procedures for obtaining repeatable particulate emissions measurements over more aggressive driving cycles. These studies should include measurement of particulate mass emissions, chemical composition and size distributions.
- The ARB's source profile for gasoline vehicles should be updated to include organic carbon, while the sulfate contribution should be reduced substantially
- To obtain more accurate source profiles, data on particulate composition for larger fleets of vehicles are needed. These measurements should include elemental and organic carbon and PAHs.
- Further studies of fuel effects on particulate emissions should include more replicate testing on a specific cycle for statistical verification and larger numbers of vehicles. For mass emissions, the more significant differences will probably be observed during the cold start or for older vehicles. Chemical analyses measurements should be expanded to include PAH emissions, since there is some evidence from this study that fuel may affect the organic fraction of the particulate.
- Measurements of the chemical composition and PAH and nitro-PAH profiles should be obtained as a function of particle size. Such information would further our understanding of gas-to-particle conversion and the mechanisms of particle dynamics and PAH-particle association.

1.0 INTRODUCTION

In an effort to improve the air quality in non-attainment areas, the Clean Air Act Amendments of 1990 have mandated that government agencies develop implementation plans for emission control strategies. The State Implementation Plan (SIP) for California requires the accurate forecasting of emissions inventories for the assessment of realistic and appropriate control strategies. As it relates to mobile sources, this assumes the availability of a large and representative database of mass emission rates for both gaseous and particulate emissions. Although several recent studies have added considerably to the database on particulate emissions from normal and high-emitting vehicles (Norbeck et al., 1998; Norbeck et al., 1996; Whitney, 1998; Cadle et al., 1997a; Cadle et al., 1997b; Sagebiel et al., 1997), these data are still limited from the standpoint of emissions inventory development. In addition, few studies to date have investigated fuel effects or the effects of different driving cycles on particulate emissions from gasoline vehicles.

The present program is designed to increase our knowledge of particulate emission rates from gasoline-fueled vehicles representative of the modern fleet, provide a characterization of the size distributions and chemical composition of these emissions, and assess the effects of vehicle operating condition, driving cycle, and fuel type on particulate emission rates. The program was divided into two phases. Phase 1 was designed as a baseline data gathering effort to examine driving cycle and fuel effects on particulate mass emissions and composition for different technology gasoline vehicles. The results of Phase 1 were used to develop the protocols for Phase 2, where the emphasis was on the development of particulate emission factors for the UC.

2.0 EXPERIMENTAL PROCEDURES

2.1 Test Fuels and Fuel Procurement

Phase 1

For Phase 1 of the program, a pre-1992 California summertime unleaded gasoline and a post-1996 California Phase 2 summertime reformulated gasoline (RFG) were used as test fuels. Both fuels were procured from Phillips Chemical Company in Bartlesville, OK. Fuel analyses were conducted at CE-CERT at the beginning of testing to verify the fuel specifications and at the end of testing to ensure the integrity of the fuel had not been compromised during use. Analyses included specific gravity, distillation, Reid Vapor Pressure, and detailed hydrocarbon analysis for aromatics, olefins, benzene, and MTBE. The specifications for the pre-1992 California average unleaded gasoline and the post-1996 California Phase 2 gasoline and analysis results are presented in Table 1.

Table 1. Properties of Test Fuels used in Phase 1

Fuel Parameter	Units	California Pre-1992 gasoline		California Phase 2 Gasoline		Mid-grade ^a Phillips Analyses	Premium ^b Phillips Analyses	CE-CERT Analyses
		Specs.	Phillips Analyses	CE-CERT Analyses	Specs.			
Octane	-	89 Min.	89.1	-	89 Min.	89.9	92.7	-
Distillation	Deg. F	75-100	95	94	Report 130-150	102 139	99	96
Initial BP	Deg. F	120-140	122	120	190-210	144 199	143	152
10% Point	Deg. F	200-230	205	200	290-300	197 297	209	210
50% Point	Deg. F	300-325	305	303	390 max.	296 385	298	299
90% Point	Deg. F	415 max.	383	366	30-40	376 38.2	385	380
End Point	Ppmw	125-175	162	149.5	6.7-7.0	30.3 7.0	38.2 6.9	42.3
Sulfur	Psi	8.7-9.0	8.9	8.7	4.5	4.4 4.4	4.7 4.0	6.7 4.7
RVP	vol %	9.0-11.0	9.4	9.1	22-25	23.95 23.8	22.1 13.8	22.5 13.35
Olefins	vol %	29.0-35.0	32.0	33.2	12-14	12.98 13.8	13.44	-
Aromatics	vol %	18-24	20.3	20.6	-	-	-	-
Multi-Substituted Alkyl	-	-	-	-	-	-	-	-
Aromatics	vol %	Report	50.1	Report	46.6	49.6	-	-
Paraffins	vol %	1.4-2.0	1.44	1.24	0.8-1.0	0.78	0.90	0.79
Benzene	vol %	0	0.0	0.0	10.8-11.2	10.95 10.9	11.0	10.9
MTBE	vol %	0	-	-	-	-	-	-
Ethanol	Gram/gal	0.005 max.	0.00	0.05 max.	0.00	0.0	0.0	0.0
Lead	Gram/gal	0.005 max.	0.000	0.005 max.	0.000	0.0	0.0	0.0
Phosphor	wt %	Report	86.3	Report	83.8	84.2	-	-
Carbon	wt %	Report	13.7	Report	14.2	13.8	-	-
Hydrogen	-	Control	No	Yes	Yes	Yes	-	-
Deposit	-	-	-	-	-	-	-	-
Additives (yes/no)	-	-	-	-	-	-	-	-

a - For tests conducted on Datsun 310 and Ford Mustang

b - For tests conducted on Ford Tempo

Phase 2

All testing for Phase 2 was conducted using a post-1996 California Phase 2 gasoline obtained from Phillips Chemical Company. Fuel analyses were conducted by the California Air Resources Board (CARB) at the beginning of the program to verify the fuel specifications and in the middle and at the end of testing to ensure the integrity of the fuel had not been compromised during use. Analyses conducted by CARB include measurements for API gravity, distillation, aromatics, oxygenates, olefins, benzene, Reid Vapor Pressure, and sulfur. The properties of this fuel and analysis results are presented in Table 2.

Table 2. Properties of Test Fuel used in Phase 2

Fuel Parameter	Units	Specs.	California Phase 2 Gasoline	
			Phillips Analyses	CARB Analyses
Octane	-	91 Min.	92.4	
Specific Gravity			0.7377	0.7373
Distillation				
Initial BP	deg. F	Report	102.4	
10% Point	deg. F	130-150	139.7	
50% Point	deg. F	190-210	204.7	201
90% Point	deg. F	290-300	296.7	291
End Point	deg. F	390 max.	367.1	
Sulfur	Ppmw	30-40	35	33.7
RVP	Psi	6.7-7.0	6.95	6.80
Olefins	vol %	4-6	4.9	4.5
Aromatics	vol %	22-25	24.3	24.62
Multi-Substituted Alkyl	vol %	12-14	12.5	
Aromatics				
Paraffins	vol %	Report		
Benzene	vol %	0.8-1.0	0.82	0.79
MTBE	vol %	10.8-11.2	10.95	10.75
Ethanol	vol %			
Lead	gram/gal	0.05 max.	0.0	
Phosphor	gram/gal	0.005 max.	0.000	
Carbon	wt %	Report	84.0	
Hydrogen	wt %	Report	14.0	
Deposit Control		Yes	Yes	
Additives (yes/no)				

a - For tests conducted on Datsun 310 and Ford Mustang

b - For tests conducted on Ford Tempo

2.2 Vehicle Recruitment

Phase 1

In Phase 1, three vehicles representative of distinctly different emission control technologies were tested. The vehicles were a 1990 Ford Tempo with multi-point fuel injection (MPFI) and a three-way catalyst (TWC); a 1981 Datsun 310 with an oxidation catalyst (OC) and carburetion; and a non-catalyst-equipped 1967 Ford Mustang. Descriptions of these test vehicles are provided in Table 3. These vehicles were recruited from the general UC Riverside population of faculty, staff, and students. Since the vehicles were not selected randomly, each of the three vehicles was given an initial FTP emissions test to ensure the vehicles were not excessive emitters. These vehicles did not exceed four times the 50,000 mile California certification standard for non-methane hydrocarbon (NMHC) or total hydrocarbon (THC), carbon monoxide (CO), and nitrogen oxides (NO_x) for the respective model year or five times the standard for these emissions for the 1980 and older test vehicle.

Table 3. Descriptions of Test Vehicles for Phase 1

Model Year	1990	1981	1967
Manufacturer	Ford Tempo GL	Datsun 310	Ford Mustang
Engine Family	4 Cylinder	4 Cylinder	8 Cylinder
Mileage	70,932	118,577	92,374*
Fuel Delivery System	Multi-point fuel injection	Carbureted	Carbureted
Emission Control System	Three-way Catalyst	Oxidation Catalyst	Non-Catalyst

* Probable rollover

Phase 2

For Phase 2, the vehicle matrix was enlarged and designed to be representative of the California vehicle fleet based on percentages provided by CARB staff. Within each category, the vehicle breakdowns were based on manufacturer (domestic/foreign), fuel delivery technology (carbureted/throttle-body, MPFI) and emissions control system (non-catalyst, OC, TWC). The target test matrix for Phase 2 is presented in Table 4. The actual vehicle list and descriptions by category is presented in Table 5. Vehicles for Phase 2 were all randomly recruited using a mailing list generated from a Department of Motor Vehicles (DMV) database.

Table 4. Target Vehicle Test Matrix for Phase 2

Manufacturer Breakdown		
Model Years	Domestic	Foreign
1955-1974	1	0
1975-1980	2	2
1981-1985	4	3
1986+	6	6

Technology Breakdown		
Model Years	Technology Type	
1955-1974	non-catalyst	1
1975-1980	Oxidation catalyst	4
1981-1985	Throttle-body/carbureted/TWC	5
1986+	Multipoint fuel injection/TWC	2
	Throttle-body/carbureted/TWC	2
	Multipoint fuel injection/TWC	10

Table 5. Vehicle List for Phase 2

Make, Model, Model Year	Mileage	Engine Type/Size	Fuel Delivery	Emission Control System
<i>Pre-1975</i>				
1 1972 Chevy Caprice	108,418	V-8 6.6 L	Carburetor	non-catalyst
<i>1975-1980</i>				
<i>Domestic</i>				
1 1980 Chevy Caprice	144,191	V-8 5.0 L	Carburetor	OC
2 1979 Plymouth Horizon	162,444	4 cyl. 1.7 L	Carburetor	OC
<i>Foreign</i>				
1 1980 Honda Prelude	173,793	4 cyl. 1.8 L	Carburetor	OC
2 1979 Datsun 210	134,674	4 cyl. 1.4 L	Carburetor	OC
<i>1981-1985</i>				
<i>Domestic</i>				
1 1985 Olds. Cutlass Sierra	154,165	4 cyl. 2.5 L	TBI	TWC
2 1985 Cadillac Seville	160,100	V-8 4.1 L	TBI	TWC
3 1983 Ford Fairmont	129,081	6 cyl. 3.3 L	Carburetor	TWC
4 1983 Ford LTD Wagon	103,230	V-6 3.8 L	Carburetor	TWC
<i>Foreign</i>				
1 1984 Nissan Maxima	122,279	6 cyl. 2.4 L	MPFI	TWC
2 1984 Mazda 626	164,298	4 cyl. 2.0 L	Carburetor	TWC
3 1984 BMW 318i	209,202	4 cyl. 1.8 L	MPFI	TWC
<i>1986+</i>				
<i>Domestic</i>				
1 1995 Ford Mustang	31,671	V-8 5.0 L	MPFI	TWC+OC
2 1994 Dodge Shadow	95,518	4 cyl. 2.5 L	TBI	TWC
3 1993 Plymouth Sundance	89,330	4 cyl. 2.2 L	TBI	TWC
4 1990 Ford Tempo	81,989	4 cyl. 2.3 L	MPFI	TWC
5 1988 Ford Taurus	126,816	V-6 3.0 L	MPFI	TWC
6 1987 Buick Park Avenue	91,408	V-6 3.8 L	MPFI	TWC
<i>Foreign</i>				
1 1996 Toyota Camry	27,467	4 cyl. 2.2 L	MPFI	TWC
2 1992 Toyota Corolla	73,757	4 cyl. 1.6 L	MPFI	TWC
3 1992 Honda Civic	99,906	4 cyl. 1.5 L	MPFI	TWC
4 1990 Nissan Stanza	96,954	4 cyl. 2.4 L	MPFI	TWC
5 1989 Toyota Celica	109,700	4 cyl. 2.0 L	MPFI	TWC
6 1987 Acura Legend	102,997	4 cyl. 1.6 L	MPFI	TWC

TBI = throttle-body injection; MPFI = multi-point fuel injection; TWC = 3-way catalyst; OC = oxidation catalyst

2.3 Vehicle Testing

Phase 1

Each of the three Phase 1 vehicles was tested over the FTP and Unified Cycle to obtain mass emission rates for total particulate, THC, NMHC, CO, and NO_x. Additional particulate sampling for the collection of samples for size-segregation and chemical analysis is outlined in Section 2.4.1. Each vehicle was tested using both the pre-1992 California average gasoline and the post-1996 California Phase 2 gasoline. For the newest vehicle (1990 Ford Tempo), 2-4 iterations of the FTP and 3 iterations of the UC were used to obtain a sufficient particle sample for mass analysis. For the other two vehicles (1979 Datsun 310 and 1967 Ford Mustang) only a single iteration of the full FTP and UC were conducted on each fuel. Replicate tests were conducted on all three vehicles to evaluate the variability of the experimental measurements. Replicate tests were conducted over only bag 2 of the FTP and UC. Two to four replicate FTP bag 2s were performed to collect a sufficient sample while single replicate bag 2s were used for the UC. Gaseous emissions were not collected on the 4 iteration FTP bag 2s due to sampling limitations. Vehicles were fueled and preconditioned using procedures developed as part of the Auto/Oil program (Burns et al., 1991), as outlined in Appendix A.

Phase 2

For Phase 2, all vehicles were tested over the UC to obtain mass emissions rates for particulate, THC, NMHC, CO, and NO_x. The particulate sampling procedures are discussed in Section 2.4.2, including procedures for sampling for size distributions and chemical analysis. Each vehicle was tested over 1 to 3 full iterations of the UC (depending on its model year) to obtain a sufficient particulate sample:

- Newer vehicles (1986+) with anticipated low particulate emission rates were tested over three UCs.
- 1981-1985 vehicles were tested over two UCs.
- 1980 and older vehicles were tested over only a single UC.

Two replicate tests were conducted over bag 2 of the UC on each vehicle to assess the variability of emissions measurements. Vehicles were preconditioned and refueled using procedures similar to those used in the Auto/Oil program (Burns et al., 1991). Phases 1 and 2 of the UC were substituted for the LA4 cycles, however, to provide a more aggressive preconditioning since the results of Phase 1 of this study, as well as the results for other studies (Cadle et al., 1997b; Norbeck et al., 1996), indicate that preconditioning plays an important role in determining particulate mass emission rates.

All tests for Phase 1 and Phase 2 were conducted in CE-CERT's Vehicle Emission Research Laboratory (VERL) equipped with a Burke E. Porter 48-inch single-roll electric dynamometer and Pierburg CVS/dilution tunnel system. Particulate sampling was conducted with VERL's 10-inch diameter dilution tunnel. A CVS flow rate of 350 SCFM was used for the FTP testing. A

higher CVS flow rate of 493 SCFM was used for most of the UC tests to ensure that adequate dilution over the more aggressive UC for larger displacement engines. Phase 1 UC testing for the 1990 Ford Tempo and 1981 Datsun 310 was conducted using a CVS flow rate of 350 SCFM since this provided adequate dilution for these smaller displacement engines.

2.4 Particulate Sample Collection

The particulate sampling protocol for this project was designed to provide mass emissions rates, size distributions, and samples for analysis for organic and elemental carbon fractions, trace elements and ions, and, for Phase 2, speciation of the organic fraction of the particulate. The sampling configuration, filter media, and analyses are presented in Figure 1 and summarized below.

2.4.1 Particulate Sampling for Phase 1

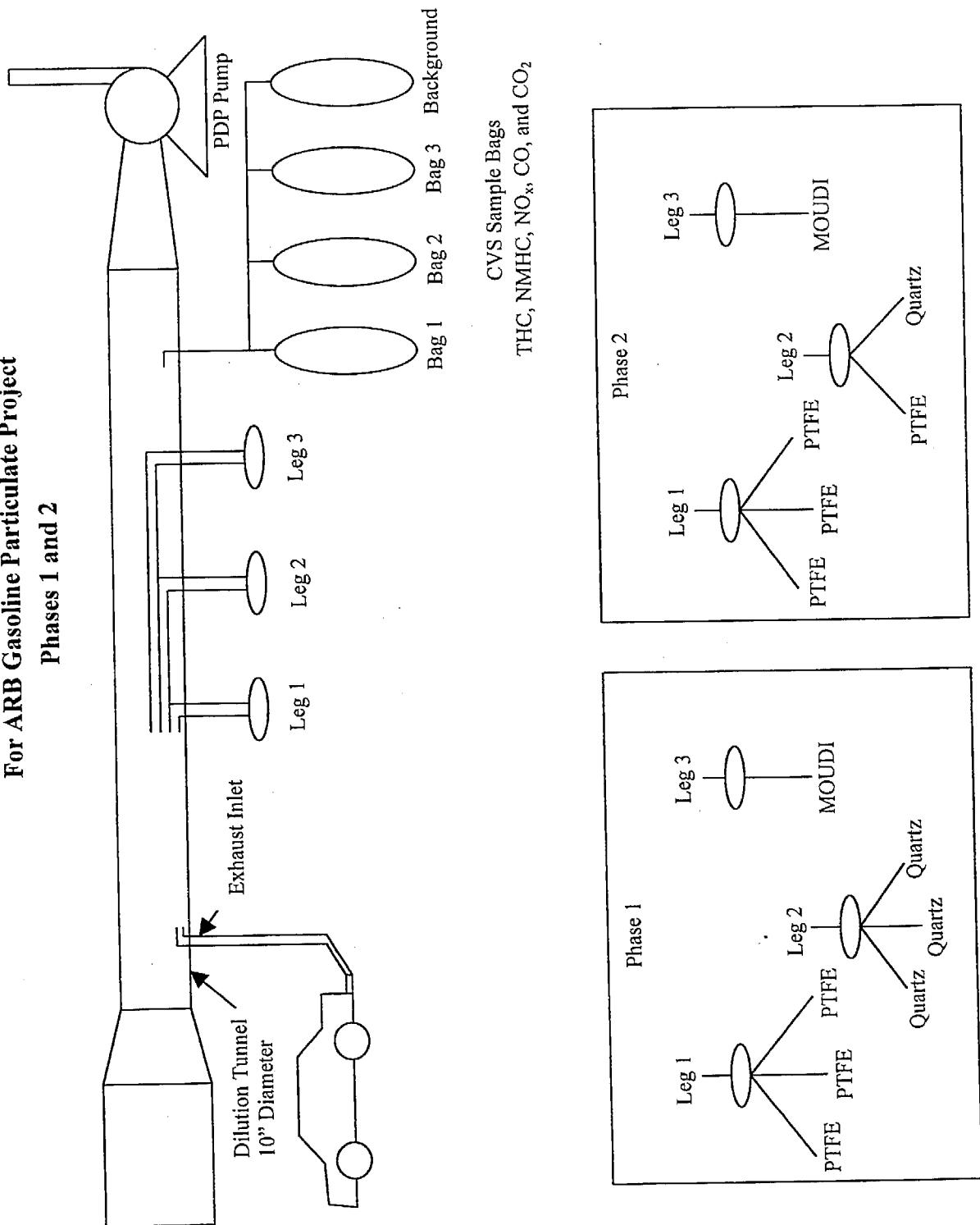
The sampling configuration, filter media, and analyses are as follows for Phase 1:

- Probe 1 was fitted with 47 mm, 2.0 μm Gelman Teflon membrane filters using a Pierburg particle sampling system to obtain total mass particulate emission rates and samples for elemental analysis by x-ray fluorescence (XRF) for each phase of the FTP or UC. This probe holds three filter assemblies with automatic sampling for each phase of the UDDS. Each filter assembly was fitted with a primary and a backup filter.
- Probe 2 was fitted with prefired Pallflex 2500 QAT-UP quartz fiber filters to obtain particulate samples for organic and elemental carbon analyses and ion analyses for each phase of FTP or UC.
- Probe 3 was fitted with a MOUDI cascade impactor for collection of size segregated samples. Uncoated aluminum foils were used for impaction substrates together with 47 mm, 2.0 μm pore size Gelman Teflon membrane after-filters. The MOUDI was configured using the stages corresponding to cut-points of >18, 10, 3.2, 1.8, 1.0 μm aerodynamic diameter and an after filter for particulates below 1.0 μm . This allows the determination of the total mass below 10.0, 2.5, and 1.0 μm aerodynamic diameter.

For each test, mass emission rates were determined for each phase of the FTP and UC. Samples for chemical analysis on quartz-fiber filters and Teflon membrane filters were also collected for each phase of the FTP and UC for Phase 1. Samples for chemical analysis were submitted for each vehicle/fuel/cycle combination. MOUDI samples were collected cumulatively over the entire FTP or UC cycle.

The sampling for total particulate mass and collection of samples for XRF analysis by phase of the FTP and UC (Probe 1) were collected at 70 lpm. Quartz fiber filters for chemical analyses by phase were sampled at 47 lpm, while MOUDI samples were collected at 30 lpm. All sampling was performed under isokinetic conditions.

**Figure 1. Dilution Sampling
For ARB Gasoline Particulate Project
Phases 1 and 2**



2.4.2 Particulate Sampling for Phase 2

The particulate sampling protocol differed slightly from that used in Phase 1. Specifically, additional sampling was added to the protocol to allow the collection of samples for analysis of polynuclear aromatic hydrocarbons (PAHs), hopanes, and steranes. Also, samples for chemical analysis of organic and elemental carbon, trace elements, and ions were collected cumulatively rather than separately for each bag as in Phase 1. The differences and similarities in the sampling configuration are summarized below:

- Probe 1 was fitted with Teflon membrane filters using a Pierburg particle sampling system to obtain total mass particulate emission rates. Mass emission rates were determined for each phase of the UC using a flow rate of 47 lpm.
- Probe 2 was fitted with a three-way flow splitter. One filter holder was fitted with prefired Pallflex 2500 QAT-UP quartz fiber filters for organic and elemental carbon analyses, and detailed speciation of the particulate PAHs, hopanes and steranes. Thin stainless steel rings were placed in front of the quartz fiber filters to provide a more uniform and well defined deposit for carbon analysis. The quartz filters were backed up using a vapor-phase trap for PAHs consisting of XAD-4 resin (polystyrene, divinylbenzene polymer) sandwiched between two polyurethane foam plugs. The other filter holder was fitted with 47 mm Gelman Teflon membrane filters for analysis of trace elements and ions. Samples for chemical analysis on quartz-fiber filters and the PUF/XAD substrate, and Teflon membrane filters were collected cumulatively over the entire UC at flow rates of 60 lpm and 30 lpm, respectively. Samples for 10 of the 24 test vehicles were submitted for analysis in Phase 2.
- Probe 3 was fitted with a MOUDI cascade impactor for collection of size segregated samples. The MOUDI configuration was the same as in Phase 1 to allow the determination of the total mass below 10.0, 2.5, and 1.0 μm aerodynamic diameter. MOUDI samples were collected cumulatively over each UC.

2.5 Particulate Sample Analysis

Teflon membrane and aluminum MOUDI substrates were weighed before and after sampling to determine the collected mass using an ATI Orion ultra-microbalance. The microbalance is located in an environmental weighing chamber maintained at a temperature of $25\pm0.5^\circ\text{C}$ and a relative humidity of $40\pm5\%$. Before and at the completion of sample collection, substrates were preconditioned for at least 24 hours in the environmental chamber before weighing. Tunnel blanks for mass emission measurements were collected daily and converted to mass emission rates based on sample flows and the length of the testing period. Mass emissions data are all presented corrected for the daily tunnel blank.

The Teflon membrane filters were utilized for analysis of metals and other trace elements in both Phase 1 and Phase 2. In Phase 1, these filters were collected from probe 1 for each phase of the FTP or UC. For Phase 2, these filters were collected from probe 2 cumulatively over the entire UC. All analyses were conducted by the Desert Research Institute (DRI). Samples were stored in petri dishes in a refrigerator until they were shipped to DRI in a cooler with blue ice packs.

Quartz fiber filters collected by bag were used for ion analyses in Phase 1 of the project. In Phase 2, Teflon membrane filters were used for these analyses instead of quartz fiber filters to ensure a sufficient sample for extraction of PAHs/hopanes/steranes. Samples were also collected cumulatively in Phase 2. Filters for ion analyses were extracted in a 60:40 mixture of isopropyl alcohol and distilled, deionized water for nitrate and sulfate analyses using ion chromatography. A separate extraction with distilled, deionized water was used for analysis of chloride and ammonium ions, since the isopropyl alcohol causes interference in the measurements of these two ions. Chloride ions were measured using ion chromatography, while ammonium ions were measured using automated colorimetry.

The quartz fiber filters collected at probe 2 were used for elemental and organic carbon analyses in both Phases 1 and 2. Samples were collected by bag in Phase 1 and cumulatively in Phase 2. Quartz fiber filters were obtained from DRI after prefiring at 900°C for three hours to reduce background carbon levels. The filters were shipped in blue ice to CE-CERT and stored in a refrigerator until use. Filters were stored in a freezer in petri dishes lined with aluminum foil prior to return shipment to DRI in a cooler with blue ice packs. Elemental and organic carbon analyses were performed by DRI using the Thermal Optical Reflectance (TOR) method (Chow et al., 1993) on a 0.512 cm² punch from the filter.

PAH, hopane and sterane analyses were performed on the PUF/XAD vapor-phase trap and quartz fiber filters in Phase 2. PUF/XAD backup cartridges were utilized to collect gas phase PAH, hopanes and steranes. XAD resin and PUF cartridges are obtained precleaned from DRI. The XAD resin is cleaned by washing with distilled water, followed by Soxhlet extraction for 24 hours with methanol. After draining the resin, an additional Soxhlet extraction for 24 hours with dichloromethane (CH_2Cl_2) is performed. The resin is dried in a vacuum oven at 40°C. PUF cartridges are cleaned by first washing with distilled water followed by Soxhlet extraction for 24 hours in acetone, followed by Soxhlet extraction for 24 hours in 10% diethyl ether in hexane. The extracted PUFs are dried in a vacuum oven connected to a water aspirator and dried at room temperature for approximately 2-4 hours. XAD resin and PUF cartridges were stored in a freezer before and after sampling prior to return to DRI. XAD and PUF filters were shipped from DRI to CE-CERT and from CE-CERT back to DRI in a cooler with blue ice.

The PUF/XAD vapor trap was combined with the quartz fiber filter from the corresponding test for extraction. This provides a combined sample of gaseous and particulate phase PAHs, hopanes and steranes. Filters were extracted in dichloromethane for 8 hours. Before extraction, deuterated internal standards were added to each sample. Extracts were analyzed by electron impact (EI) GC/MS technique.

3.0 PHASE 1 RESULTS AND DISCUSSION

3.1 Phase 1 – Driving Cycle and Fuel Effects on Vehicles for Three Technology Groups

3.1.1 Scope of Analysis

Phase 1 was designed as a scoping study to examine the potential impacts of fuel composition and driving cycle effects on particulate emissions of different technology vehicles. The test matrix included a series of replicate tests to allow a statistical evaluation of the results. Analysis of variance (ANOVA) tests were conducted to assess the statistical significance of any fuel or driving trends and provide confidence levels for the results. In general, the Phase 1 results indicated that driving cycle had a significant effect on particulate emissions, with higher particulate emissions for the UC than the FTP. The fuel effects varied from vehicle to vehicle. Based on these results, the UC was adopted as the test cycle for Phase 2.

3.1.2 Results

The gaseous and particulate emission data for each test on the 1990 TWC Ford Tempo, the 1981 OC Datsun, and the non-catalyst 1967 Ford Mustang are presented in Appendix B.

3.1.3 Driving Cycle Effects

A statistical summary of the driving cycle effects for the Ford Tempo, Datsun 310 and Ford Mustang is presented in Appendix C. For particulate emissions, all three vehicles show a statistically significant effect at the 95% confidence level (i.e., p-values less than or equal to 0.05) of higher particulate emissions on the UC than the FTP. Bag 2 particulate emissions from the Datsun 310 and Ford Mustang were substantially higher for the UC than for the FTP. For the Datsun 310, similar trends are also observed for bag 1 and the weighted total, and to a lesser extent for bag 3. For the Ford Mustang, the same trends are observed for bags 1 and 3 for the pre-1992 fuel, but not for RFG. The driving cycle effect is smaller for the Ford Tempo. For bag 2 on the Tempo, particulate emissions were approximately 70% higher for the UC than for the FTP. This effect was observed on both fuel types but was statistically significant only for RFG. A similar trend of particulate emissions for the UC is also observed in bags 1 and 3 for both fuels for the Ford Tempo.

For both the Datsun 310 and the Ford Mustang, THC, NO_x, and CO emissions are higher for the UC than for the FTP on both fuels over bag 2. Except for NO_x emissions from the Ford Mustang using the pre-1992 fuel, all of these trends were statistically significant. Similar trends were also observed for both vehicles for bags 1 and 3. For the Ford Tempo, NO_x emissions were elevated on the UC for both fuels. The Tempo results were statistically significant in all cases except bag 3 for the pre-1992 fuel. The results for THC and CO emissions show greater variability, which makes analysis more difficult. The statistical significance of trends for these measurements is limited and in some cases conflicting. It should be noted that care must be taken when comparing the weighted values for the FTP and the UC since bag 2 is considerably longer than bags 1 and 3 for the UC. Thus, bag 2 makes a larger contribution to the weighted value for the UC than it does for the FTP.

3.1.4 Fuel Effects

A statistical summary of the fuel effects for the Ford Tempo, Datsun 310 and Ford Mustang is presented in Appendix D. For the Ford Mustang, particulate, THC and CO bag 2 emissions were lower on RFG than on pre-1992 gasoline over both cycles, but NO_x emissions were higher for RFG. The effects of fuel on particulate, THC and CO emissions were all statistically significant, but the trends for NO_x emissions were not. Trends similar to those observed in bag 2 are observed for bags 1 and 3 for the Mustang.

For the Datsun 310, the differences in bag 2 gaseous emissions for the two fuels are small. A statistically significant reduction in bag 2 FTP CO and NO_x emissions is observed for RFG, however. Analysis of bag 1 emissions indicates a trend of lower gaseous emissions for RFG, while bag 3 gaseous emissions were low with no detectable trends due to fuel effects. For particulate emissions, the bag 2 results for RFG were unexpectedly higher than for the pre-1992 fuel; on the UC, this result was statistically significant. This result is most likely attributable to the vehicle preconditioning rather than an actual fuel effect. As discussed below in the Phase 2 results section, even with a more aggressive preconditioning procedure the replicate tests over bag 2 of the UC cycle often are quite variable, with particulate emissions typically lower than for the initial test(s). The importance of preconditioning has also been suggested by other researchers (Cadle et al., 1997b; Norbeck et al., 1996). Analysis of the bag 1 particulate emissions indicates a significant reduction for the Phase 2 gasoline, while bag 3 particulate emissions were low and did not show a significant fuel trend. It should be noted that preconditioning effects of particulate emission rates for bags 1 and 3 is probably less than for bag 2 of the UC since these bags have less severe driving.

For the Ford Tempo, fuel differences do not have a significant impact on particulate emissions. The replicate bag 2 results demonstrate essentially no difference in the particulate emissions between RFG and pre-1992 gasoline over either driving cycle. Similar results are observed for bag 3. Only for bag 1 is there an indication that fuel differences may affect particulate emissions. For gaseous emissions, there were no significant trends with regard to fuel effects. Although some statistically significant fuel effects were found for specific bags of the FTP and UC, they were not consistent trends over both cycles. It should be noted that in studies by Chou and Long (1996), statistically significant differences between pre-1992 gasoline and RFG were not observed for MPFI vehicles for either THC or CO emissions, although NO_x emissions were lower at a statistically significant level for RFG. Also, the test-to-test variability for this particular vehicle made it difficult to quantify trends in gaseous emissions for both fuel and cycle differences on the Ford Tempo. At least part of this variability appears to be associated with the time interval between the start of testing in July and the completion of testing in November - December.

3.2 Chemical Analysis Results and Vehicle, Driving Cycle, and Fuel Effects

The results of the chemical analyses for Phase 1 are presented graphically in Figures 2 to 4, respectively, for the TWC Ford Tempo, the oxidation catalyst Datsun 310, and the non-catalyst Ford Mustang. For these graphs, all elements are grouped together. The mass emission rates for all chemical species for each vehicle are presented in Table 6. These values were obtained by averaging over the weighted values for each fuel/cycle combination for each vehicle. These data

Figure 2. Chemical Mass Emission Rates for Ford Tempo

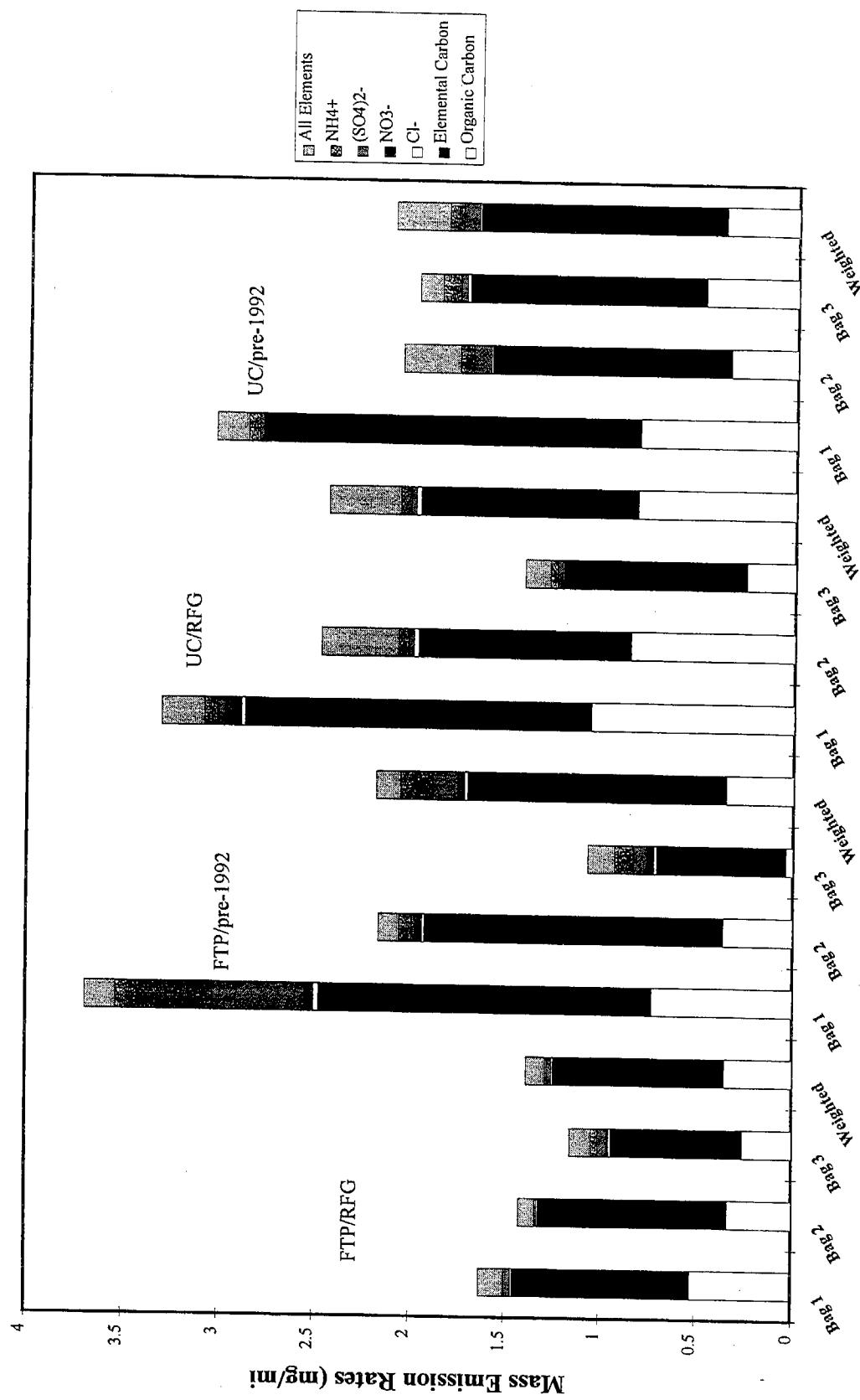


Figure 3. Chemical Mass Emission Rates for Datsun 310

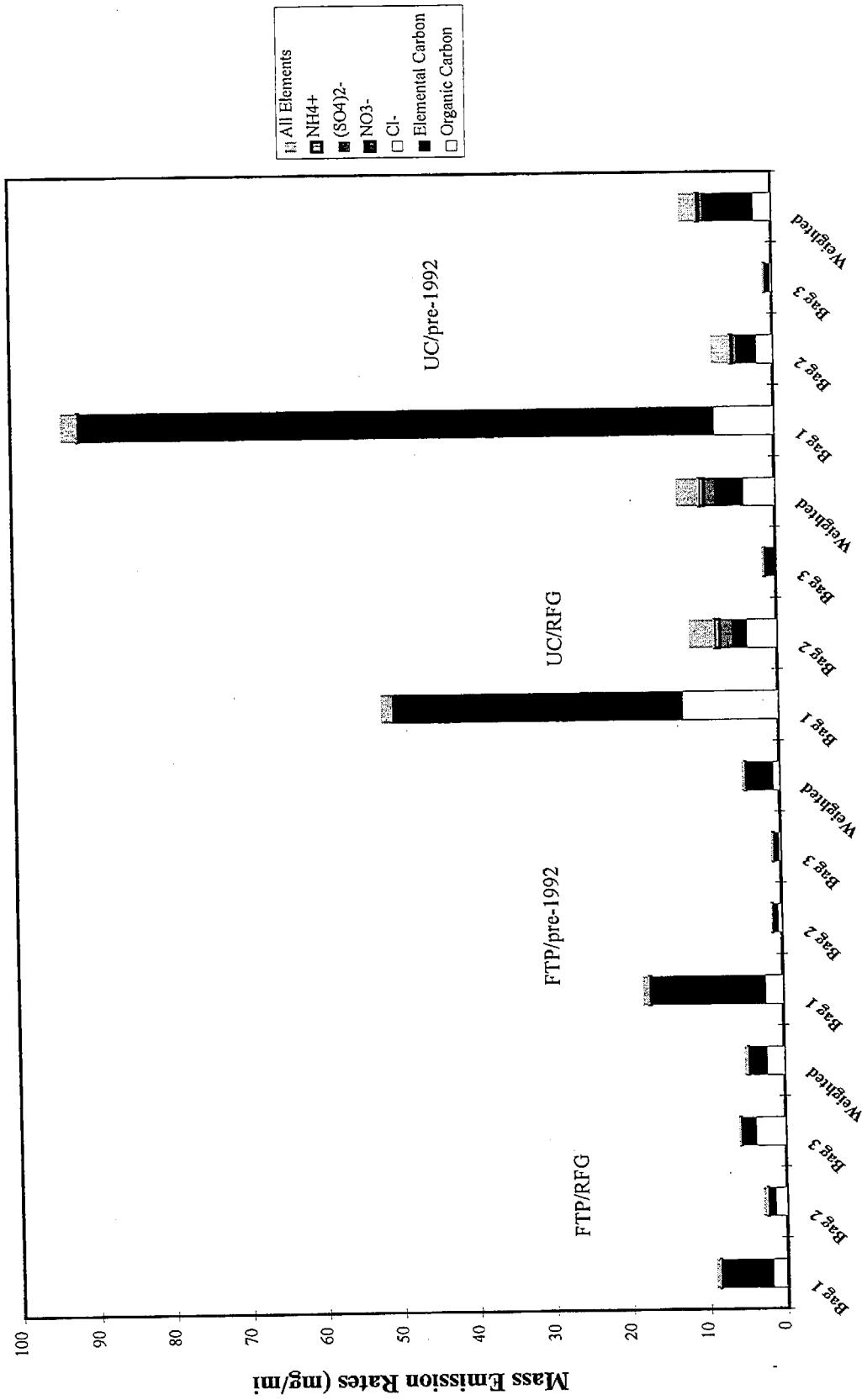


Figure 4. Chemical Mass Emission Rates for Ford Mustang

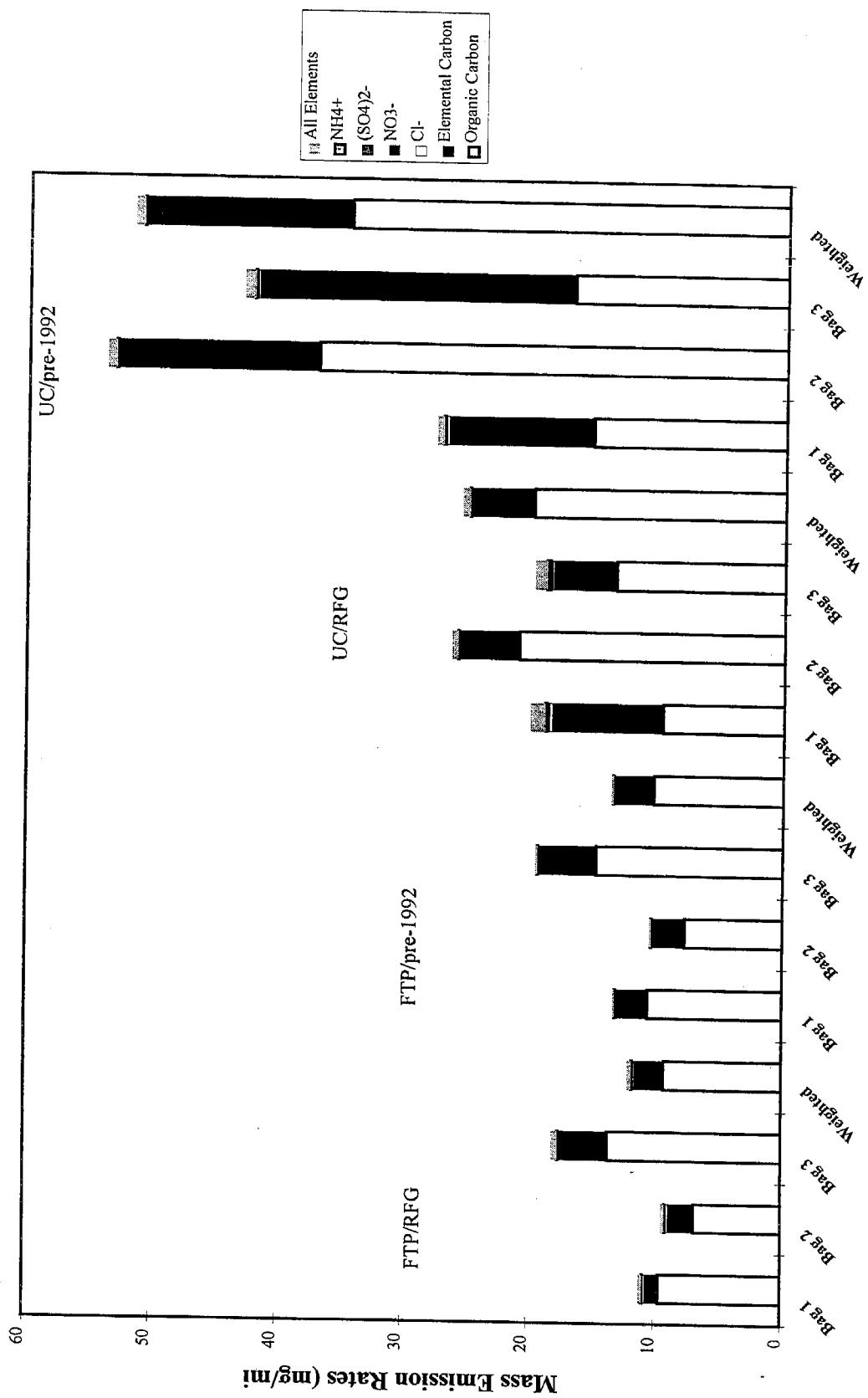


Table 6. Summary of Chemical Mass Emission Rates (mg/mi)

	Ford Tempo		Datsun 310		Ford Mustang	
	Average	Ave. Uncert.	Average	Ave. Uncert.	Average	Ave. Uncert.
Cl ⁻	0.0147	0.0099	0.0457	0.0237	0.0720	0.0449
NO ₃ ⁻	0.0022	0.0066	-0.0115	0.0114	-0.0280	0.0201
(SO ₄) ²⁻	0.0670	0.0092	0.5117	0.0528	0.0598	0.0211
NH ₄ ⁺	0.0739	0.0160	0.2662	0.0405	0.0691	0.0456
OC	0.4739	0.0802	2.2926	0.2235	18.4362	1.6132
EC	1.1689	0.0911	4.0264	0.2994	6.6584	0.5480
Na	-0.0040	0.0061	0.0060	0.0161	0.0476	0.0211
Mg	0.0050	0.0021	0.0109	0.0060	0.0244	0.0066
Al	0.0017	0.0016	0.0028	0.0049	0.0029	0.0084
Si	0.1311	0.0110	0.9281	0.0778	0.1779	0.0147
P	0.0054	0.0008	0.0108	0.0012	0.0258	0.0030
S	0.0220	0.0016	0.3679	0.0320	0.0445	0.0038
Cl	0.0090	0.0010	0.0048	0.0025	0.0058	0.0029
K	-0.0002	0.0005	-0.0003	0.0016	0.0001	0.0039
Ca	0.0069	0.0006	0.0242	0.0019	0.0038	0.0040
Tl	0.0006	0.0033	0.0004	0.0063	0.0000	0.0169
V	0.0002	0.0014	0.0002	0.0031	0.0001	0.0082
Cr	0.0002	0.0004	0.0005	0.0008	0.0027	0.0022
Mn	0.0001	0.0002	0.0008	0.0005	0.0013	0.0013
Fe	0.0156	0.0011	0.0531	0.0039	0.0371	0.0029
Co	0.0001	0.0003	0.0001	0.0006	0.0003	0.0010
Ni	0.0002	0.0002	0.0004	0.0003	0.0001	0.0008
Cu	0.0046	0.0003	0.0009	0.0003	0.0018	0.0007
Zn	0.0074	0.0005	0.0138	0.0011	0.0103	0.0009
Ga	0.0000	0.0003	0.0001	0.0006	0.0002	0.0013
As	0.0000	0.0003	0.0002	0.0033	0.0003	0.0016
Se	0.0000	0.0002	0.0000	0.0003	0.0001	0.0008
Br	0.0004	0.0002	0.0009	0.0003	0.0003	0.0007
Rb	0.0000	0.0001	0.0000	0.0003	0.0000	0.0007
Sr	0.0001	0.0001	0.0000	0.0003	0.0000	0.0007
Y	0.0000	0.0002	0.0000	0.0004	0.0001	0.0009
Zr	0.0002	0.0002	0.0007	0.0004	0.0017	0.0011
Mo	0.0007	0.0003	0.0241	0.0018	0.0002	0.0020
Pd	0.0001	0.0011	0.0001	0.0022	0.0004	0.0056
Ag	-0.0001	0.0013	-0.0001	0.0025	-0.0002	0.0066
Cd	0.0001	0.0013	0.0010	0.0026	0.0029	0.0068
In	0.0005	0.0016	0.0016	0.0030	0.0044	0.0079
Sn	0.0013	0.0020	0.0024	0.0036	0.0054	0.0092
Sb	0.0018	0.0022	0.0006	0.0046	0.0043	0.0121
Ba	0.0044	0.0084	0.0026	0.0170	0.0064	0.0449
La	0.0022	0.0117	0.0056	0.0226	0.0250	0.0599
Au	0.0000	0.0005	0.0001	0.0010	0.0000	0.0022
Hg	0.0000	0.0004	0.0001	0.0007	0.0004	0.0017
Ti	0.0000	0.0003	0.0001	0.0009	0.0003	0.0017
Pb	0.0007	0.0004	0.0314	0.0024	0.0023	0.0018
U	0.0000	0.0003	0.0000	0.0006	0.0000	0.0016
Total	1.9818	0.1254	8.4118	0.4044	25.6165	1.7161

Note: Bold numbers indicate averages that are at least twice the average uncertainty

Table 7. Summary of Percentages of Chemical Components

	Ford Tempo		Datsun 310		Ford Mustang	
	Average	Ave. Uncert.	Average	Ave. Uncert.	Average	Ave. Uncert.
Cl ⁻	0.72%	0.52%	0.62%	0.38%	0.49%	0.28%
NO ₃ ⁻	0.18%	0.34%	-0.30%	0.18%	-0.15%	0.12%
(SO ₄) ²⁻	3.48%	0.47%	3.37%	0.42%	0.24%	0.12%
NH ₄ ⁺	3.70%	0.83%	2.07%	0.49%	0.29%	0.27%
OC	22.65%	4.00%	27.20%	2.81%	67.57%	5.35%
EC	60.03%	4.51%	47.20%	3.57%	20.76%	1.60%
Na	-0.19%	0.32%	0.07%	0.22%	0.28%	0.10%
Mg	0.26%	0.12%	0.12%	0.10%	0.13%	0.03%
Al	0.08%	0.08%	0.05%	0.07%	0.01%	0.04%
Si	5.39%	0.44%	7.44%	0.59%	0.49%	0.04%
P	0.26%	0.04%	0.14%	0.02%	0.10%	0.02%
S	1.11%	0.08%	2.57%	0.22%	0.14%	0.01%
Cl	0.39%	0.04%	0.05%	0.03%	0.02%	0.02%
K	0.00%	0.03%	-0.01%	0.03%	0.00%	0.02%
Ca	0.35%	0.03%	0.28%	0.02%	0.01%	0.03%
Tl	0.04%	0.18%	0.00%	0.10%	0.00%	0.10%
V	0.01%	0.08%	0.00%	0.05%	0.00%	0.05%
Cr	0.01%	0.02%	0.00%	0.02%	0.01%	0.01%
Mn	0.00%	0.01%	0.01%	0.01%	0.00%	0.01%
Fe	0.78%	0.05%	0.53%	0.03%	0.16%	0.01%
Co	0.00%	0.01%	0.00%	0.01%	0.00%	0.01%
Ni	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%
Cu	0.25%	0.02%	0.01%	0.00%	0.01%	0.00%
Zn	0.36%	0.03%	0.14%	0.01%	0.04%	0.00%
Ga	0.00%	0.01%	0.00%	0.01%	0.00%	0.01%
As	0.00%	0.02%	0.00%	0.04%	0.00%	0.01%
Se	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
Br	0.02%	0.01%	0.01%	0.00%	0.00%	0.00%
Rb	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
Sr	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%
Y	0.00%	0.01%	0.00%	0.01%	0.00%	0.01%
Zr	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%
Mo	0.04%	0.02%	0.25%	0.02%	0.00%	0.01%
Pd	0.01%	0.06%	0.00%	0.03%	0.00%	0.03%
Ag	0.00%	0.07%	0.00%	0.04%	0.00%	0.04%
Cd	0.01%	0.07%	0.01%	0.04%	0.01%	0.04%
In	0.03%	0.08%	0.03%	0.05%	0.03%	0.05%
Sn	0.07%	0.11%	0.03%	0.06%	0.02%	0.06%
Sb	0.10%	0.12%	0.01%	0.07%	0.02%	0.07%
Ba	0.22%	0.46%	0.04%	0.26%	0.06%	0.26%
La	0.14%	0.63%	0.12%	0.35%	0.16%	0.35%
Au	0.00%	0.03%	0.00%	0.01%	0.00%	0.01%
Hg	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%
Ti	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%
Pb	0.03%	0.02%	0.32%	0.02%	0.01%	0.01%
U	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%
Total	98.67%	6.24%	90.67%	4.82%	90.35%	-5.65%

Note: Bold numbers indicate averages that are at least twice the average uncertainty

are presented as a percentage of total mass in Table 7. The error of each measurement is calculated by propagating the uncertainty for the chemical analysis and sampling volumes. Chemical components whose concentrations are at least twice the analytical uncertainty are shown in bold in the tables. Complete chemical mass emissions rates for all vehicle tests are presented in Appendix E along with a breakdown of total carbon to inorganic carbon as a percentage of the total mass.

3.2.1 Elemental and Organic Carbon

The results presented in Figures 2 to 4 show that elemental and organic carbon are the primary constituents for gasoline particulate emissions. The percentages of total carbon identified as elemental and organic carbon are presented Figures 5 to 7 for the Ford Tempo, Datsun 310, and the Ford Mustang. These data are presented as relative organic-to-elemental carbon splits, as opposed to percent of total mass, since there is a large variability in the total mass identified through chemical analysis, as shown in Table 7 and Appendix E. This result has been observed by other researchers (Hildeman et al., 1991; Watson et al., 1994; Sagebiel et al., 1997; Cadle et al., 1998), and could be attributed in part to the fact that not all of the species that contribute to the particulate composition are measured. Another possible explanation is the impact of filter inhomogeneities on carbon analysis, which uses only a small section of the filter. In some cases, the sample collected was also relatively small or the overall mass emission rate low, making it more difficult to obtain consistent comparisons between the gravimetric measurements and the chemical analysis results.

For the Ford Tempo, elemental carbon represents the larger fraction for all samples. The elemental-to-organic split varies more from sample to sample for the Datsun, although on the average elemental carbon predominates. The opposite trend is observed for the non-catalyst Ford Mustang, where organic carbon composed a larger fraction. Oxidation over the catalyst can explain the lower lower levels of organic carbon for the Ford Tempo and Datsun. Catalysts have been demonstrated to be effective in reducing the organic fraction of particulate from previous studies of diesel particulates (Zelenka et al., 1990).

3.2.2 Ions and Elements

Inorganic species represent a smaller portion of the sample and are consistent from vehicle to vehicle on a mg/mi basis. The average combined weighted emission rates for elements and ions were 0.34, 2.09, and 0.52 mg/mi for the Ford Tempo, Datsun and Ford Mustang, respectively. Elements and ions compose a larger fraction of the total particulate matter for the vehicles with the lower mass emission rates. These constituents represent an average of 16.0 and 16.3% of the total weighted particulate for the Ford Tempo and the Datsun, but only 2.0% of the total weighted particulate for the Ford Mustang.

The mass emission rates for the individual non-carbonaceous species with average concentrations at least twice the average analytical uncertainty are plotted in Figures 8 to 10. Of the elements, 13 had average concentrations that were at least twice the average analytical uncertainty for one or more vehicles. These elements were Na, Mg, Si, P, S, Cl, Ca, Fe, Cu, Zn, Br, Mo, and Pb. Elemental S is possibly fuel-derived, but overall S does not make a large

Figure 5. Carbon Percentage Fractions for Ford Tempo

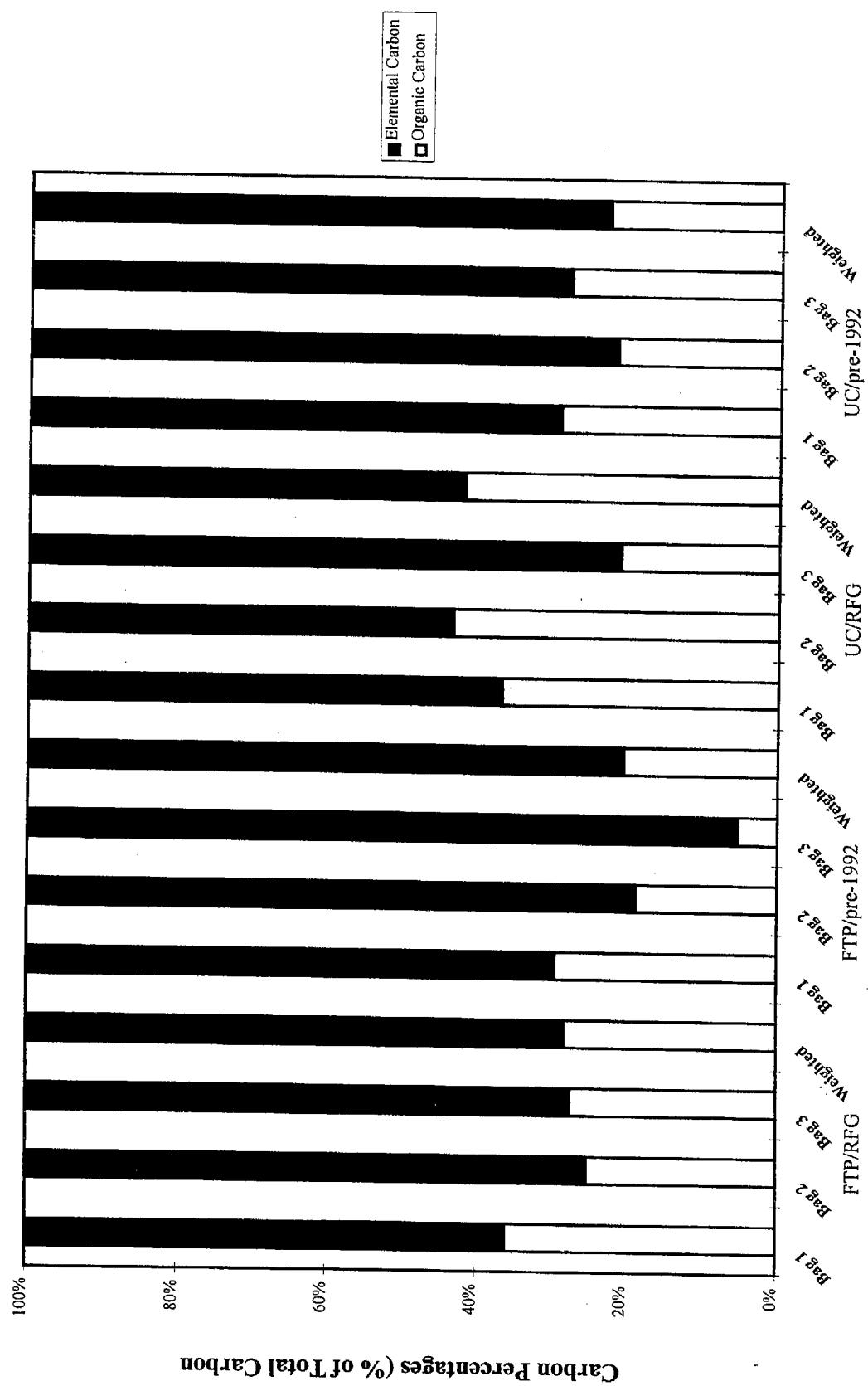


Figure 6. Carbon Percentage Fractions for Datsun 310

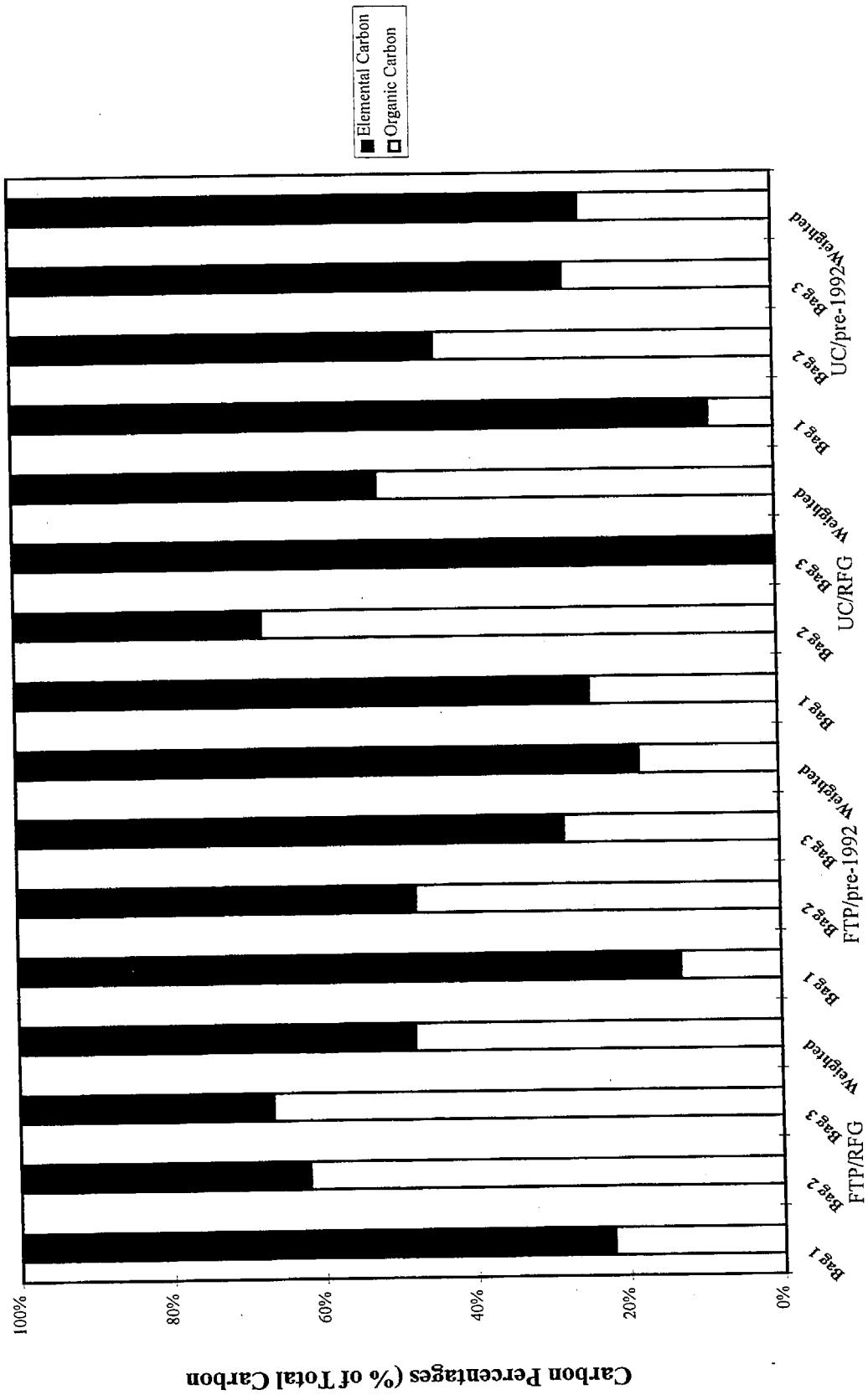


Figure 7. Carbon Percentage Fractions for Ford Mustang

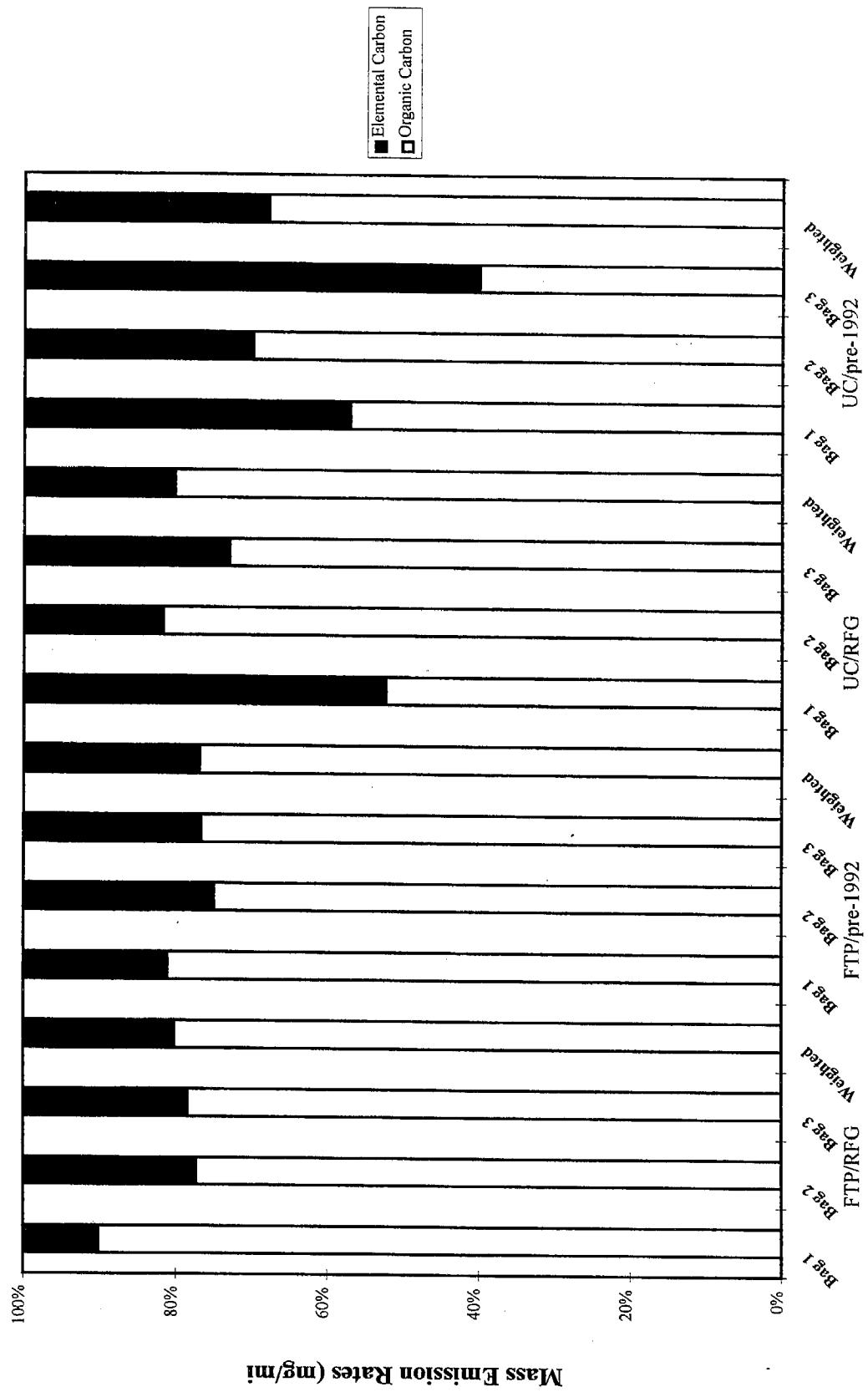


Figure 8. Ion and Element Mass Emission Rates for Ford Tempo



Figure 9. Ion and Element Mass Emission Rates for Datsun 310

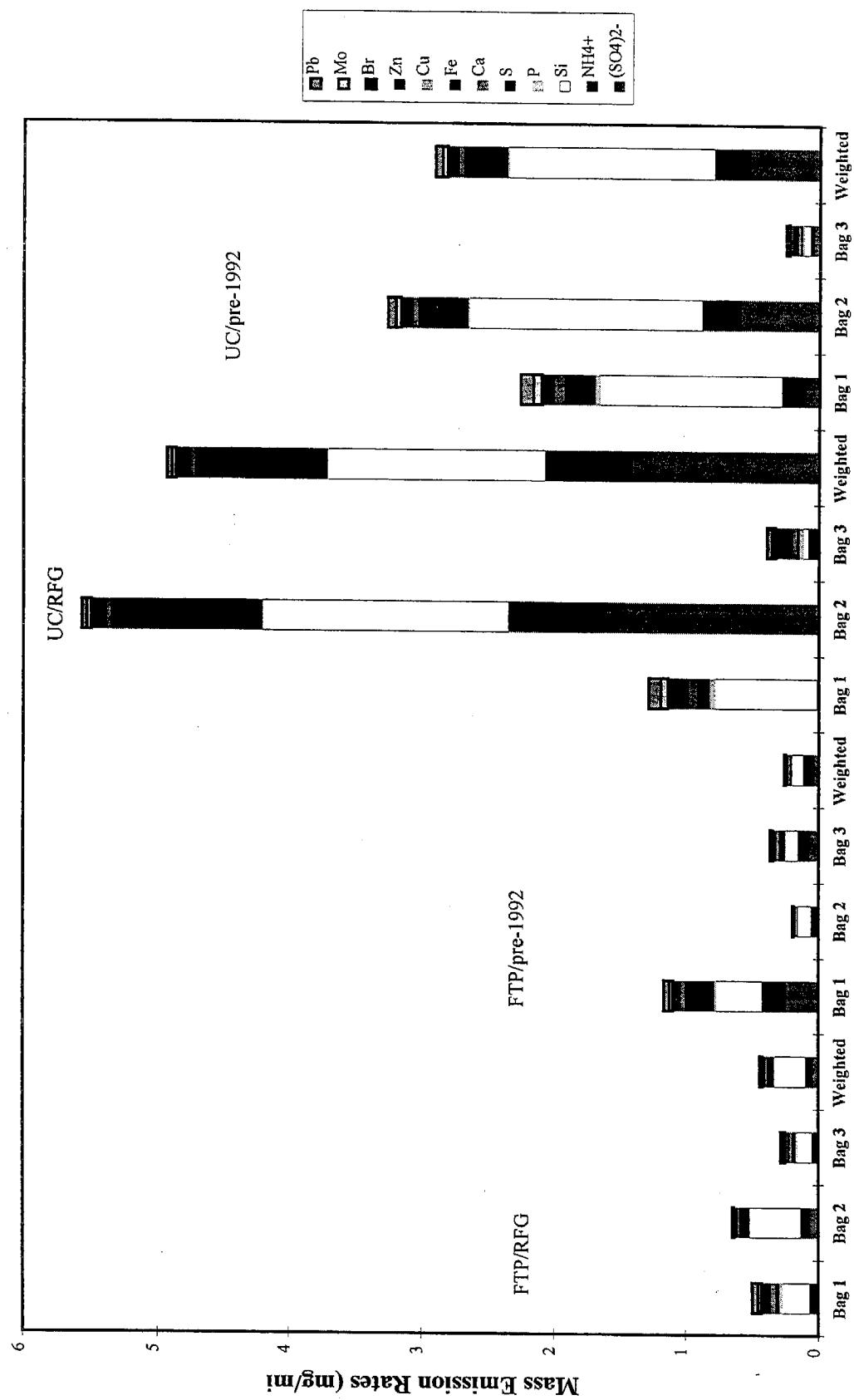
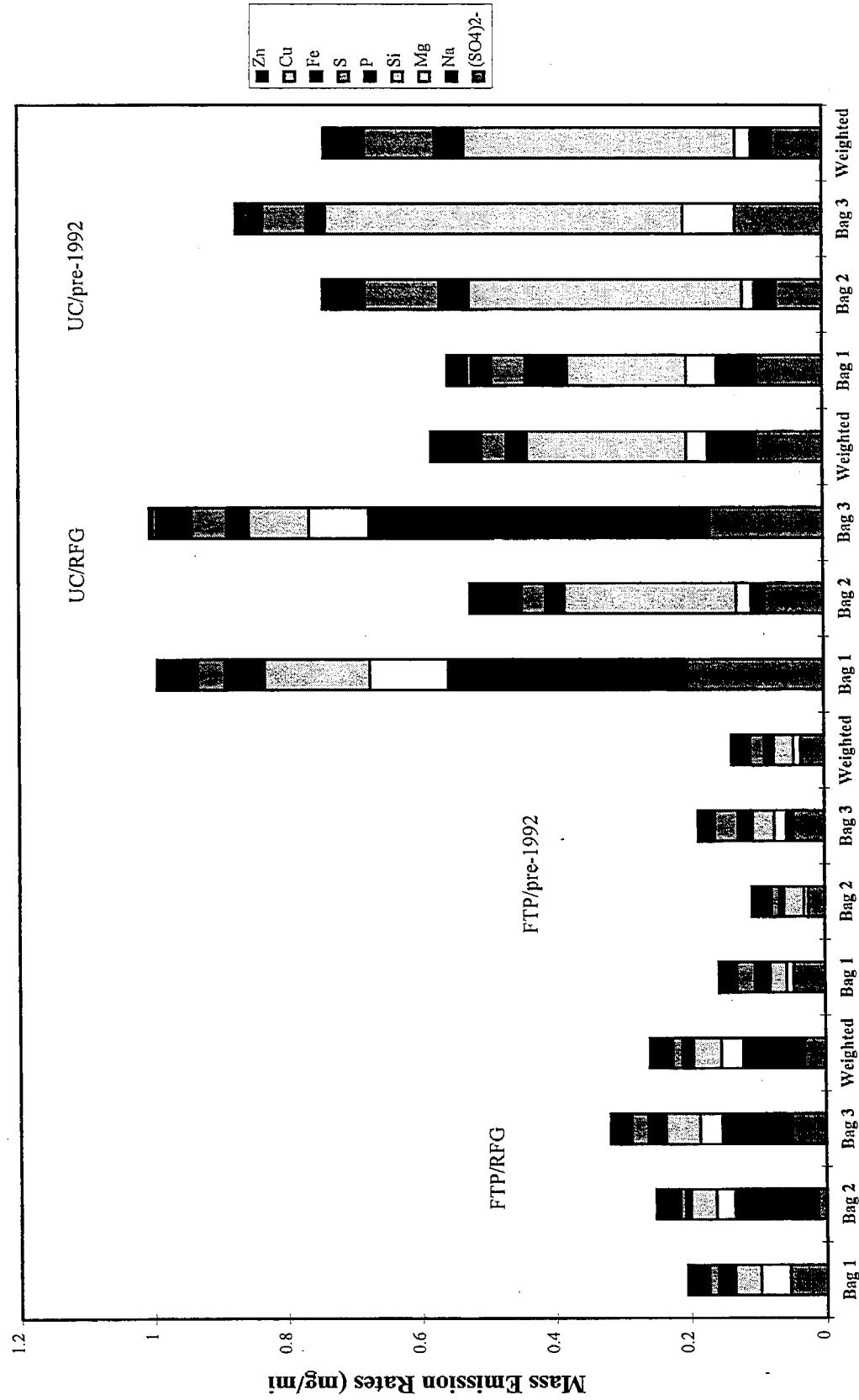


Figure 10. Ion and Element Mass Emission Rates for Ford Mustang



contribution to the total particulate. Si and Fe have both been observed in previous studies of gasoline particulate. Si emissions rates, in particular, were relatively high for some tests in the pilot study. The Si mass emission rates are similar to those observed in the Orange County Remote Sensing study (Cadle et al., 1997b), where the average pre-repair emission rate of elemental Si was 1.27 mg/mi (0.65 mg/mi with outliers removed). Elements such as Mg, P, Ca, Cu, and Zn have all been observed in previous studies of gasoline particulates (Cadle et al. 1997b). These elements are all commonly present in engine oil.

3.2.3. Statistical Analysis

3.2.3.1 Vehicle Effects

Analysis of Variance (ANOVA) tests were conducted to investigate differences between the chemical composition of particulate emissions from different vehicles. The results of these analyses are presented in Appendix F for organic and elemental carbon fractions. The table shows the organic and elemental carbon fractions obtained by averaging the weighted emission results for each of the four fuel/cycle combinations for each vehicle, and a corresponding p-value from the ANOVA analysis. P-values less than or equal to 0.05 indicate that there are statistically significant differences between the carbon fractions for different vehicles at a 95% confidence level. In cases where statistically significant differences were observed, an additional Fischer's protected least square difference test was applied to determine which vehicle pairs were statistically different. These results are included in the table. This analysis shows that the differences in organic and elemental fractions for the catalyst-equipped Tempo and Datsun are statistically different from those of the non-catalyst Mustang at the 95%confidence level.

ANOVA analyses were conducted for ions and elements with concentrations that were at least twice the average uncertainty on at least one vehicle. These data are presented in Appendix F on a mass emission rate basis and on a percentage basis. Most statistically significant differences between vehicles were relatively small — less than 0.1 mg/mi or less than 1% of the total particulate. The largest differences were observed for elemental Si. On a percentage basis, the overall trend that combined ion and element emissions composed a larger fraction of the total particulate for the Ford Tempo and Datsun compared to the Ford Mustang was statistically significant at the 95% confidence level.

3.2.4 Fuel, Cycle, and Bag Effects

ANOVA analyses were performed for each vehicle to investigate fuel, cycle and bag effects on particulate composition. These analyses were somewhat limited by the lack of replicate tests, so it was difficult to identify significant trends in the data. For fuel and cycle effects, a two-way ANOVA was performed using only the weighted emission results from each of the four fuel/cycle combinations on each vehicle. The results of these ANOVA analyses for carbon fractions are presented in Appendix G for each of the test vehicles. For fuel effects, the only statistically significant effect found was that organic carbon levels were higher with RFG than with pre-1992 gasoline for the Datsun. A similar trend was observed for the Ford Tempo and Ford Mustang, although the results were not statistically significant. For all three vehicles, driving cycle had a small and not statistically significant effect on carbon fractions.

ANOVA analyses also were performed for each vehicle to investigate fuel and cycle effects on the emissions of particulate ions and elements. The results for the Ford Tempo, Datsun, and Ford Mustang are presented in Appendix G. These tables include only the elements that were found at levels twice the analytical uncertainty of the measurement for at least one vehicle. Although some statistically significant differences are observed, most of these differences are well below 0.1 mg/mi. For the Datsun, a statistically significant increase in Si emissions was found on the UC compared with the FTP. Sulfate and S emissions were also higher for the Datsun on the UC, although this result was not statistically significant. It is worth noting that the combined emissions for all ions and elements for all three vehicles were higher for the UC than the FTP. This is consistent with the overall higher particulate emissions observed for the more demanding Unified Cycle.

ANOVA analyses were conducted to determine the effects of each bag on particulate composition. These results are presented in Appendix H for elemental and organic carbon, ions and elements. For elements, the only difference between bags that was statistically significant and greater than 0.1 mg is that Si emissions were higher on bag 2 of the UC than on bag 1 or 3 for the Ford Tempo and the Datsun. Sulfate and S emissions were also higher for bag 2 of the UniC for the Datsun. These results are consistent with the overall trend of higher combined ion and elemental emissions for these vehicles over bag 2 of the UC compared with bags 1 and 3. It probably can be attributed to the more aggressive nature of the driving in bag 2.

3.2.5 Replicates

Several tests were performed to evaluate the repeatability of the chemical analysis measurements over different tests. The results of replicate Unified Cycle tests for Ford Tempo are presented in Appendix I for all chemical species analyzed. These two tests show similar chemical profiles, with many of the same species identified in both tests. The relative mass emission rates for individual species also compare well between the tests. Additional replicate tests for organic and elemental carbon were also conducted. The results of the replicate organic and elemental measurements are presented in percent of total carbon in Appendix I. Three of the replicate organic/elemental measurements varied by less than 5%, but the relative organic and elemental percentages for one test varied by about 20%.

3.3 Size Distribution Data

The MOUDI data are presented in Table 8 for each of the three test vehicles. The MOUDI data for both the Datsun 310 and Ford Mustang are consistent with expected size distributions for particles dominated by combustion-derived sources, with 85 to 90% of the particulate mass being below 1.0 mm in diameter. For the Ford Tempo, a considerably larger fraction of the particulate mass appears to be greater than 1.0 μm . One possible explanation is that as the engine-out emissions decrease, the contribution from sources of larger particulate matter (such as particles re-entrained in the tailpipe) becomes more important. This trend is not observed for the lower-emitting vehicles in Phase 2. This could be attributed to the more aggressive preconditioning, which may help to remove re-entrained particulate from the vehicle system.

Table 8. Particulate Size Distributions for MOUDI Tests

Cycle	Fuel	Mass Percentage		
		<10 µm	<2.5 µm	<1.0 µm
1990 Ford Tempo				
FTP	Calif. Phase 2	80.8%	68.6%	55.9%
FTP	Calif. Pre-1992	83.8%	66.7%	55.4%
Unified Cycle	Calif. Phase 2	77.4%	57.6%	49.5%
Unified Cycle	Calif. Pre-1992	80.7%	52.6%	34.6%
	Ave.	80.7%	61.4%	48.9%
1981 Datsun 310				
FTP	Calif. Phase 2	95.7%	90.0%	89.6%
FTP	Calif. Pre-1992	94.9%	90.1%	79.4%
Unified Cycle	Calif. Phase 2	97.2%	91.0%	84.3%
Unified Cycle	Calif. Pre-1992	97.5%	92.3%	85.0%
	Ave.	96.3%	90.9%	84.6%
1967 Ford Mustang				
FTP	Calif. Phase 2	91.5%	85.5%	80.3%
FTP	Calif. Pre-1992	96.8%	92.7%	89.6%
Unified Cycle	Calif. Phase 2	96.3%	91.6%	87.8%
Unified Cycle	Calif. Pre-1992	98.3%	96.5%	93.8%
	Ave.	95.7%	91.6%	87.9%

3.4 Phase 1 Summary

Driving cycle had the most significant effect on particulate emissions, with all vehicle technologies showing a statistically significant effect of higher particulate emissions on the UC than the FTP. This effect was largest on an absolute and relative basis for the oxidation and non-catalyst vehicles. Fuel composition had a smaller effect on particulate emissions than driving cycle, and its effect varied between vehicle technologies and different bags of the driving cycles. For the non-catalyst vehicle, RFG produced lower overall particulate emissions than the pre-1992 fuel. For the oxidation catalyst vehicle, the particulate emissions were higher for the pre-1992 gasoline for bag 1, but lower for bag 2. The result for bag 2 probably can be attributed to the preconditioning of the vehicle. For the TWC vehicle, fuel differences had essentially no effect on particulate emissions with the possible exception of bag 1 emissions. RFG resulted in a trend of lower THC, CO, and NO_x emissions for the oxidation catalyst vehicle and lower THC and CO emissions for the non-catalyst vehicle. The effects on gaseous emissions for the TWC vehicle were varied and may have been impacted by vehicle repeatability.

The chemical breakdowns showed that elemental and organic carbon are the primary constituents of gasoline particles. Lower percentages of organic carbon relative to elemental carbon are observed for the catalyst-equipped Ford Tempo and Datsun than for the non-catalyst Ford Mustang. Inorganic species comprised a smaller portion of the particulate and included sulfate,

elemental Si and S. Overall mass emissions rates for inorganic species were relatively consistent from vehicle to vehicle, but inorganic species compose a larger fraction of the total particulate matter on a percentage basis for the catalyst-equipped vehicles with lower mass emission rates. Driving cycle did not have a significant impact on the organic to elemental fractions of the particulate, but the combined emissions of all ions and elements were consistently higher for the UC than the FTP. The particulate composition was not strongly fuel-dependent. Although some differences were observed between different bags for elemental and organic carbon for different vehicles and cycles, these differences were not statistically significant. Combined ion and elemental emission rates were higher for bag 2 of the UC compared to bags 1 and 3, probably due to the more aggressive nature of bag 2 of the UC.

4.0 PHASE 2 RESULTS AND DISCUSSION

4.1 Particulate Emissions Results

A summary of the UC weighted particulate emissions results for the Phase 2 vehicle fleet is presented in Table 9. This includes average, median, maximum and minimum UC weighted particulate emission rates by model year categories. Particulate emission results for individual vehicles are presented in Table 10. Complete particulate and emission results for all Phase 2 vehicles are included in Appendix J.

The results presented in Table 9 show that the average UC particulate emission rates for newer vehicles (1986+) are relatively low. A fairly steady trend is evident of increased emissions with increasing vehicle age. There is a relatively wide range of emission rates for each of the model year categories, however. Although no other studies of UC particulate emissions have been conducted, the results for the UC testing are comparable to those obtained for FTP testing of in-use vehicles in previous studies (Norbeck et al., 1998). These data do not provide a direct comparison between FTP and UC particulate emissions, however, as the results were obtained using two different fleets with high emitters making a more significant contribution to the FTP results.

Table 9. Unified Cycle Weighted Particulate Emission Rates for Phase 2

Model Year	# of vehicles	Ave. PM mg/mi	Median mg/mi	Max. PM mg/mi	Min. PM mg/mi
1955-1975	1	67.0			
1975-1980	4	47.1	27.4	126.2	7.4
1981-1985	7	20.0	22.7	35.3	5.2
1986+	12	4.5	2.9	19.3	0.7

Table 10. UC Particulate Emissions for Individual Vehicles

	Phase 1 Mg/mi	Phase 2 mg/mi	Phase 3 mg/mi	Weighted mg/mi
1986+				
1996 Toyota Camry	4.56	0.50	0.73	0.73
1995 Ford Mustang	2.83	2.87	0.61	2.71
1994 Dodge Shadow	7.26	1.56	1.24	1.84
1993 Plymouth Sundance	109.33	3.90	2.59	9.31
1992 Toyota Corolla	8.3	0.96	2.17	1.43
1992 Honda Civic	6.25	0.83	1.5	1.16
1990 Ford Tempo	1.53	3.53	0.46	3.21
1990 Nissan Stanza	25.7	4.65	1.39	5.52
1989 Toyota Celica	4.53	1.35	0.57	1.46
1988 Ford Taurus	61.49	17.82	6.57	19.31
1987 Buick Park Avenue	10.04	2.77	1.32	3.05
1987 Acura Integra	9.87	4.15	1.87	4.29
1981-1985				
1985 Oldsmobile Cutlass	15.00	4.92	1.01	5.18
1985 Cadillac Sedan DeVille	10.75	6.30	1.23	6.19
1984 Nissan Maxima	34.92	25.20	7.6	24.48
1984 Mazda 626	214.41	15.81	3.41	25.32
1984 BMW 318 I	61.76	33.47	38.47	35.30
1983 Ford LTD	25.508	21.58	7.668	20.82
1983 Ford Fairmont	38.165	22.42	14.739	22.70
1975-1980				
1980 Chevy Caprice	238.19	35.60	36.89	45.77
1980 Honda Prelude	30.95	8.09	2.74	8.92
1979 Plymouth Horizon	64.59	121.56	230.56	126.15
1979 Datsun 210	6.53	7.88	1.04	7.41
Pre-1975				
1972 Chevy Caprice	309.30	56.10	21.05	67.01

Note: Bag 2 particulate emissions do not include replicate results

Since the EMFAC model is designed to utilize bag-specific emissions, it is important to examine the differences between emission rates for different bags of the UC. Average bag-specific emission rates are presented in Table 11 for each model year category. The results show that bag 1 emissions are higher than those for bags 2 and 3 for all vehicle model year categories, as expected. The emissions for bags 2 and 3, on the other hand, are more comparable for each of the model year groupings. It should be noted that there are important differences between the bags for the UC and the FTP; hence, the relationship between bag emissions rates for the UC and FTP may differ. Bags 1 and 3 for the UC are considerably shorter than for the FTP, so emissions are probably more representative of the true "start-up" emissions for a cold or hot start. Bag 2, on the other hand, is longer in duration than bag 2 of the FTP and considerably more aggressive.

Table 11. Phase 2 Unified Cycle Particulate Matter Emission Results by Bag

		Average mg/mi	Median mg/mi	Max. mg/mi	Min. mg/mi
1955-1975	Bag 1	309.3			
	Bag 2	32.7			
	Bag 3	21.1			
1975-1980	Bag 1	85.1	47.8	238.2	6.5
	Bag 2	44.0	21.1	127.5	6.1
	Bag 3	67.8	19.8	230.6	1.0
1981-1985	Bag 1	57.2	34.9	214.4	10.8
	Bag 2	16.4	15.0	45.9	2.8
	Bag 3	10.6	7.6	38.5	1.0
1986+	Bag 1	21.0	7.8	109.3	1.5
	Bag 2	3.2	2.8	14.2	0.5
	Bag 3	1.8	1.4	6.6	0.5

Although vehicles were preconditioned rather aggressively for Phase 2, the effects of vehicle conditioning still appeared to play an important role in particulate matter emissions. Of the 24 vehicles tested in Phase 2, 16 had particulate emissions that were lower by 25% or more on the replicate bag 2 tests than on the initial test or series of tests. A summary comparison of the average bag 2 particulate emissions for the initial tests and replicate tests is presented by model year category in Table 12 and for individual vehicles in Appendix K. Also included in Table 12 are the number of vehicles in each model year category where the particulate emissions for the replicate test were reduced by more than 25% from the initial test. These data indicate that vehicle preconditioning and repeatability are important issues to address for aggressive cycles such as the UC and merit further investigation in future work. It should be noted that the importance of vehicle preconditioning has also been suggested in other studies. Cadle et al. (1997b) found that particulate matter emissions decreased for the second of two back-to-back IM240 tests in 9 out of 10 tests conducted on high emitters in Orange County, CA. Similar results were also reported by Norbeck et al. (1996) for IM240s on smoking vehicles. As described in Section 3 of this report, the Phase 1 results for the Datsun 310 also showed trends that may be attributable to vehicle conditioning.

Table 12. Comparison of Average UC Bag 2 Replicate Test Results by Model Year Category

Model Year	# of vehicles	Vehicles decreasing by >25% ^a	Average Bag 2 PM emissions From first test(s)	Average Bag 2 PM emissions from replicate test(s)	% Difference
1955-1975	1	1	56.1 mg/mi	21.0 mg/mi	-62.7%
1975-1980	4	3	43.3 mg/mi	42.1 mg/mi	-2.8%
1981-1985	7	5	18.5 mg/mi	15.3 mg/mi	-17.2%
1986+	12	7	3.7 mg/mi	3.0 mg/mi	-20.7%

^aNumber of vehicles where the particulate emissions for the replicate test were reduced by greater than 25% from the initial test

4.2 Gaseous Emission Results

Average, median, maximum, and minimum FTP weighted NMHC, CO, and NO_x emission rates by vehicle category are presented in Table 13. Overall, the average NMHC, CO, and NO_x emissions for gasoline vehicles all increase with increasing vehicle age, consistent with the particulate emission results. The gas-phase emissions also show some other trends similar to those observed for the particulate. Average bag specific emission rates for NMHC, CO, and NO_x are presented in Appendix L for each model year category. For NMHC and CO, emissions for Bag 1 are highest while emissions for Bags 2 and 3 are comparable. NO_x emissions follow a similar trend for 1981 and newer vehicles. NO_x emissions are comparable for all three bags for the 1975-1980 vehicles, and NO_x emissions are higher for bags 2 and 3 than bag 1 for the single pre-1975 vehicle. Although some vehicles exhibited lower gas-phase emissions on the replicate test than on the initial test, this trend was not as strong or consistent as with the particulate emissions. A comparison of the UC Bag 2 replicate tests for NMHC, CO and NO_x is presented in Appendix M.

4.3 Chemical Analysis Results

4.3.1 Chemical Species

Chemical analyses were performed on a subset of 10 gasoline vehicles to determine emissions for elemental and organic carbon, ions, and trace elements. These vehicles are listed in Table 14. A summary of the chemical mass emissions results for these 10 vehicles is presented in Table 15, including the average mass emission rates, standard deviations of the rates, maximum and minimum values, and average uncertainties. The error for each measurement is calculated by propagating the uncertainty for the chemical analysis and sampling volumes. Chemical components whose concentrations are at least twice the analytical uncertainty are shown in bold. Full chemical analysis results for the individual vehicles are presented in Appendix N.

The results in Table 15 show that elemental and organic carbon are the primary constituents of gasoline, consistent with the observations of other researchers. The percentage of total carbon identified as organic and elemental carbon is presented in Table 16 and Figure 11, with vehicle age increasing from left to right. On a vehicle average basis, organic carbon represented 58.7% and elemental carbon 41.3% of total carbon. Carbon percentage breakdowns varied considerably from vehicle to vehicle, however. Overall, organic carbon contributes a larger fraction of the total carbon on the older, higher-emitting vehicles. The elemental carbon fraction generally is greater for newer, lower emitting vehicles. It should be noted, however, that relatively high blank levels for organic carbon (0.71 mg/mi) made it difficult to accurately assess the contribution of organic carbon or obtain OC/EC splits for the lower emitting vehicles.

Table 13. Unified Cycle Weighted Gaseous Emission Rates for Phase 2

<i>NMHC Emissions</i>					
Model Year	# of vehicles	Ave. NMHC g/mi	Median g/mi	Max. NMHC g/mi	Min. NMHC g/mi
1955-1975	1	1.998			
1975-1980	4	1.339	0.962	3.028	0.403
1981-1985	7	1.164	0.813	2.883	0.256
1986+	12	0.472	0.260	2.157	0.098

<i>CO Emissions</i>					
Model Year	# of vehicles	Ave. CO g/mi	Median g/mi	Max. CO g/mi	Min. CO g/mi
1955-1975	1	62.537			
1975-1980	4	32.582	19.326	90.524	1.151
1981-1985	7	33.842	17.967	94.233	11.071
1986+	12	11.079	7.124	46.482	1.723

<i>NO_x Emissions</i>					
Model Year	# of vehicles	Ave. NO _x g/mi	Median g/mi	Max. NO _x g/mi	Min. NO _x g/mi
1955-1975	1	4.935			
1975-1980	4	2.428	2.131	4.326	1.125
1981-1985	7	1.344	1.236	2.259	0.532
1986+	12	0.736	0.695	1.663	0.192

Table 14. Vehicle List for Phase 2 Chemical Analysis

	Make, Model, Model Year	Technology
	1975-1980	
	Domestic	
1	1979 Plymouth Horizon	Carburetor/OC
	Foreign	
2	1980 Honda Prelude	Carburetor/OC
	1981-1985	
	Domestic	
3	1985 Olds. Cutlass Sierra	TBI/ TWC
	Foreign	
4	1984 Mazda 626	Carburetor/ TWC
	1986+	
	Domestic	
5	1994 Dodge Shadow	TBI/ TWC
6	1990 Ford Tempo	MPFI/ TWC
7	1987 Buick Park Avenue	MPFI/ TWC
	Foreign	
8	1990 Nissan Stanza	MPFI/ TWC
9	1987 Acura Legend	MPFI/ TWC
10	1989 Toyota Celica	MPFI/TWC

TBI = throttle-body injection; MPFI = multi-point fuel injection

TWC = 3-way catalyst; OC = oxidation catalyst

Table 15. Statistics for PM Emission Rates of Chemical Species (mg/mi)

	Ave	St. Dev.	Ave. Uncert.	Max.	Min
Organic	9.71	21.77	0.98	66.13	0.09
Elemental	1.92	2.33	0.18	7.17	0.27
Total Carbon	11.63	23.23	1.14	70.39	0.52
NO ₃ ⁻	0.01	0.01	0.02	0.04	0.00
SO ₄ ²⁻	0.10	0.14	0.02	0.46	0.02
Cl ⁻	0.00	0.02	0.02	0.04	-0.01
NH ₄ ⁺	0.01	0.01	0.02	0.03	-0.01
Na	-0.03	0.00	0.06	-0.02	-0.03
Mg	0.05	0.13	0.01	0.39	-0.01
Al	0.00	0.00	0.01	0.01	0.00
Si	0.29	0.28	0.03	0.84	0.01
P	0.08	0.16	0.01	0.51	0.00
S	0.06	0.11	0.01	0.34	0.01
Cl	0.02	0.02	0.00	0.05	0.00
K	0.00	0.00	0.00	0.00	0.00
Ca	0.14	0.30	0.01	0.94	0.01
Ti	0.00	0.00	0.02	0.00	0.00
V	0.00	0.00	0.01	0.00	0.00
Cr	0.00	0.00	0.00	0.01	0.00
Mn	0.00	0.00	0.00	0.01	0.00
Fe	0.24	0.42	0.02	1.35	0.01
Co	0.00	0.00	0.00	0.00	0.00
Ni	0.00	0.00	0.00	0.00	0.00
Cu	0.01	0.01	0.00	0.05	0.00
Zn	0.14	0.32	0.01	0.99	0.01
Ga	0.00	0.00	0.00	0.00	0.00
As	0.00	0.00	0.00	0.00	0.00
Se	0.00	0.00	0.00	0.00	0.00
Br	0.00	0.00	0.00	0.00	0.00
Rb	0.00	0.00	0.00	0.00	0.00
Sr	0.00	0.00	0.00	0.00	0.00
Y	0.00	0.00	0.00	0.00	0.00
Zr	0.00	0.00	0.00	0.00	0.00
Mo	0.00	0.00	0.00	0.01	0.00
Pd	0.00	0.00	0.01	0.00	0.00
Ag	0.00	0.00	0.01	0.00	0.00
Cd	0.00	0.00	0.01	0.00	0.00
In	0.00	0.00	0.01	0.00	0.00
Sn	0.00	0.00	0.01	0.00	0.00
Sb	0.00	0.00	0.01	0.00	0.00
Ba	0.01	0.02	0.04	0.04	0.00
La	-0.03	0.01	0.05	0.01	-0.04
Au	0.00	0.00	0.01	0.00	0.00
Hg	0.00	0.00	0.00	0.00	0.00
Tl	0.00	0.00	0.00	0.00	0.00
Pb	0.01	0.02	0.00	0.05	0.00
U	0.00	0.00	0.00	0.00	0.00

**Table 16. Elemental and Organic Carbon Fractions for Gasoline Vehicles
(% of Total Particulate Carbon)**

		Total PM (mg/mi)	Organic Carbon	Elemental Carbon
1994 Dodge	Shadow	1.84	45.2%	54.8%
1990 Nissan	Sentra	5.52	30.7%	69.3%
1990 Ford	Tempo	3.21	63.8%	36.2%
1989 Toyota	Celica	1.46	17.9%	82.1%
1987 Acura	Integra	4.29	70.6%	29.4%
1987 Buick	Park Avenue	3.05	37.2%	62.8%
1985 Oldsmobile	Cutlass	5.18	75.3%	24.7%
1984 Mazda	626	25.32	72.4%	27.6%
1980 Honda	Prelude	8.92	79.8%	20.2%
1979 Plymouth	Horizon	97.69	93.9%	6.1%

Inorganic species including ions and elements represented a smaller portion of the composite total. The average combined emission rates for ions and elements were 1.08 mg/mi; all but one vehicle had a mass emission rate for ions and elements less than or equal to 1.23 mg/mi. The combined mass emission rate for inorganics ranged from 0.12 to 5.60 mg/mi. On a percentage basis, inorganic species averaged 13.1% of the total mass, with a range from 4.1 to 25.7%. Of the inorganic species, 11 had average concentrations that were at least twice the average analytical uncertainty including SO_4^{2-} , Mg, Si, P, S, Cl, Ca, Fe, Cu, Zn, and Pb. The contribution of these elements on a mass emission rate basis is presented in Figure 12. These species include possible fuel derived (SO_4^{2-} , S) and oil/wear derived components (Mg, P, Ca, Zn, Fe), many of which have been observed in previous studies of gasoline vehicles (Cadle et al., 1997b; Sagebiel et al., 1997; Hildemann et al., 1991, and Watson et al., 1994). Fe and Si were the most prominent elements with average mass emission rates of 0.24 and 0.29 mg/mi. SO_4^{2-} , Ca, and Zn also had average mass emission rates of at least 0.10 mg/mi.

The source profiles for the Phase 2 test vehicles are compared with the current source profile for the ARB in Table 17. The source profile for the test vehicles is an average over all 10 vehicles, and is shown in percentage of total particulate mass. There are several important differences between the ARB's current species profiles and those obtained in this study. In particular, the species profiles obtained in this study are dominated by elemental and organic carbon, while the contribution of other species is relatively small. For the ARB's current species profiles, on the other hand, sulfate is the largest single component of the particulate. Elemental carbon composes 20% of the particulate for the ARB species profile, similar to profile from the test fleet. Organic carbon, however, is not specifically included in the ARB profile, although the "unknown" portion of the profile could include a contribution from organic carbon.

Figure 11. Carbon Percent Fractions for UC Tests

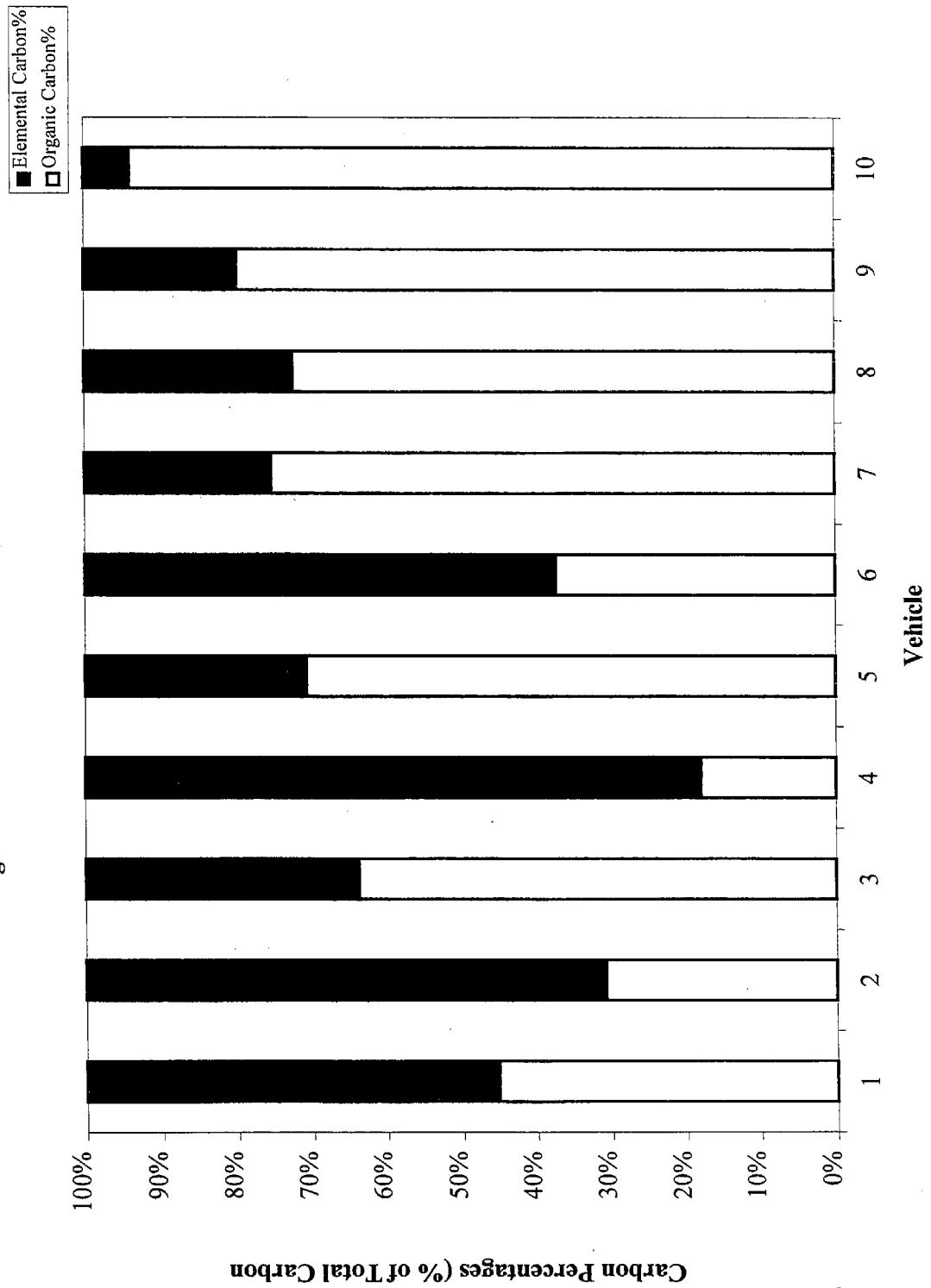
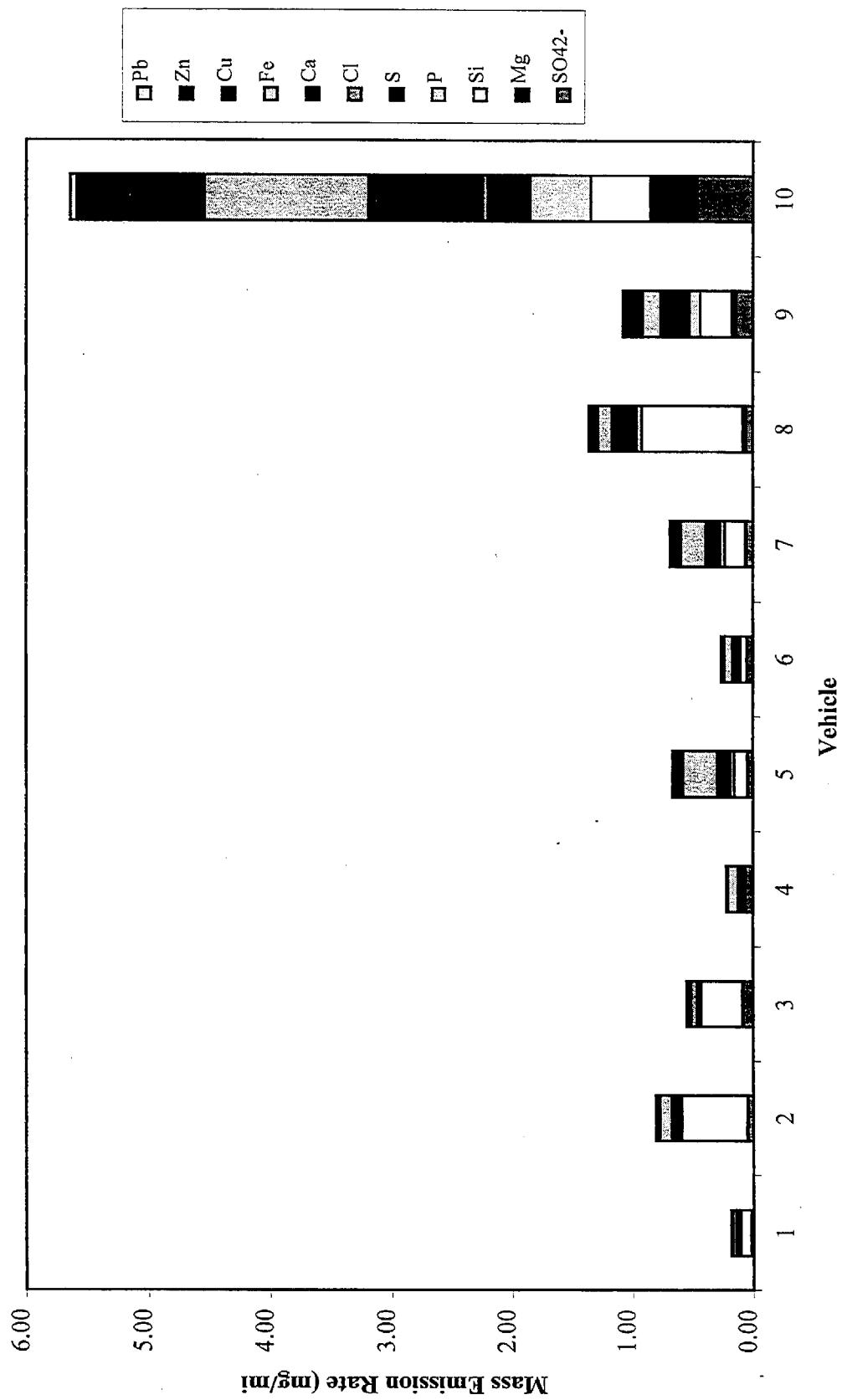


Figure 12. Chemical Mass Emission Rates



**Table 17. Comparison of Species Profiles for Phase 2 Test Fleet
vs. ARB's Current Species Profiles for Gasoline Vehicles**

	ARB's Current Source Signature	Phase 2 Test Fleet Average
Organic		40.46%
Elemental	20.00%	28.89%
NO ₃ ⁻	0.55%	0.42%
SO ₄ ²⁻	45.00%	2.23%
Cl ⁻		-0.18%
NH ₄ ⁺		0.21%
Na		-1.18%
Mg		0.03%
Al		-0.05%
Si		5.34%
P		0.52%
S		0.96%
Cl	7.0%	0.55%
K	0.01%	0.05%
Ca	0.01%	1.02%
Ti		0.01%
V		0.00%
Cr	<0.01%	0.01%
Mn	<0.01%	0.02%
Fe	<0.01%	3.46%
Co	<0.01%	0.01%
Ni	<0.01%	0.01%
Cu	<0.01%	0.06%
Zn	<0.01%	0.99%
Ga		0.00%
As		0.00%
Se		0.00%
Br	<0.01%	0.01%
Rb		0.00%
Sr		0.01%
Y		0.00%
Zr		0.00%
Mo		0.00%
Pd		0.00%
Ag		0.00%
Cd		-0.01%
In		0.01%
Sn		-0.02%
Sb		0.00%
Ba		0.32%
La		-1.22%
Au		0.00%
Hg		-0.01%
Tl		0.00%
Pb		0.06%
U		0.00%
Unknown	25.95%	17.79%

4.3.2 PAH, Hopanes, and Steranes

Table 18 summarizes the PAH emissions for the 10 vehicles analyzed. PAH results for individual vehicles are presented in Appendix O. Total PAH emission rates averaged 1,527 $\mu\text{g}/\text{mi}$ for the 10 vehicles, with a range from 63 to 7,386 $\mu\text{g}/\text{mi}$. This is slightly lower than the levels observed for higher-emitting in-use vehicles over the FTP (Norbeck et al., 1998). The distribution of PAHs is similar to that reported previously (Siegl et al., 1994; Sagebiel et al., 1997), with naphthalene, methylnaphthalenes, and dimethylnaphthalenes being primary constituents. Other PAH compounds identified include acenaphthylene, phenanthrene, methylfluorene, fluoranthene, and pyrene. Overall, total PAH emissions showed a good correlation with weighted THC emissions ($R^2 = 0.78$), but a relatively poor correlation with THC emissions ($R^2 = 0.25$). This is not surprising since previous studies have shown that PAHs are semi-volatiles found on the PUF back-up filter (Sagebiel et al., 1997).

Although the extracts from the filters and PUF/XAD traps were combined for extraction analyses, an estimate of the contribution of particulate and semi-volatile PAHs can be made based on the PAH profiles for the development of source signatures. For this estimate, PAHs with gas chromatographic retention times equal to or greater than phenethrene were classified as particulate PAHs. Although semi-volatile organic compounds are distributed in both gas and particle phases, and their distribution depends on environmental conditions, using a different phase change has relatively little impact on the overall particulate mass distributions since PAHs generally compose only a fraction of the total organic carbon. A similar approximation was made for the development of source profiles for NFRAQS (Watson et al., 1998). Based on these classifications, the contribution of the particulate PAHs and semi-volatile PAHs are compared with the total PAHs and the particulate organic carbon, as shown in Table 19. For 8 of the 10 samples, particulate PAHs composed 20% or less of the organic carbon fraction of the particulate. For the 1989 Toyota Celica, the organic carbon measurement was near the detection limits, hence organic carbon and particulate PAHs cannot be readily compared.

Analyses were also conducted for hopane and sterane emissions on the same 10 vehicles. Hopane or sterane compounds were, for the most part, not measured at levels above twice the average analytical uncertainty, however. Since hopanes and steranes are primarily oil tracers, this indicates that excessive oil burning did not make a significant contribution to the particulate composition for any of the 10 vehicles analyzed. This result also suggests that hopanes and steranes are of limited use in developing source profiles for gasoline vehicles, since their emissions are significant for only a portion of the gasoline fleet vehicles.

4.4 Particulate Size Distributions

Percent of total particulate mass emissions below 10.0, 2.5, and 1.0 μm aerodynamic diameter are summarized in Table 20 and presented for all Phase 2 vehicles in Appendix P. These results show that the majority of the particulate is below 1.0 μm in aerodynamic diameter for all vehicle categories.

Table 18. Statistics for Unified Cycle PAH emissions ($\mu\text{g}/\text{mi}$)

	ave	st dev	Uncert	Max	min
Naphthalene	612.4	979.3	68.4	3094.0	10.2
2-Methylnaphthalene	203.6	315.0	21.9	994.5	9.8
1-Methylnaphthalene	104.5	162.4	11.3	508.1	4.4
2,6+2,7-Dimethylnaphthalene	38.3	58.4	5.0	181.1	0.3
1,7+1,3+1,6-Dimethylnaphthalene	57.1	87.9	7.3	267.1	0.2
2,3+1,4+1,5-Dimethylnaphthalene	18.9	29.0	3.4	88.6	0.2
1,2-Dimethylnaphthalene	7.0	10.5	1.8	31.1	0.1
1,8-Dimethylnaphthalene	0.2	0.2	1.2	0.8	0.0
Biphenyl	21.9	32.8	2.6	105.9	0.4
2-Methylbiphenyl	-13.6	0.0	12.5	-13.6	-13.6
3-Methylbiphenyl	0.4	11.8	5.4	30.0	-5.7
4-Methylbiphenyl	1.0	6.0	2.0	16.5	-2.0
A-Trimethylnaphthalene	10.0	14.2	1.2	42.8	0.3
1-Ethyl-2-methylnaphthalene	2.3	3.8	0.4	11.4	-0.1
B-Trimethylnaphthalene	10.1	16.5	1.6	50.7	-0.3
C-Trimethylnaphthalene	9.2	15.2	1.5	47.1	-0.4
2-Ethyl-1-methylnaphthalene	0.3	0.6	0.3	1.7	0.0
E-Trimethylnaphthalene	6.5	11.4	1.1	35.7	-0.3
F-Trimethylnaphthalene	8.1	12.7	1.0	41.1	0.3
G-Trimethylnaphthalene	4.2	7.1	1.1	22.4	0.0
H-Trimethylnaphthalene	1.2	2.5	0.4	7.1	-0.2
1,2,8-Trimethylnaphthalene	0.9	1.3	0.6	3.9	-0.1
Acenaphthylene	63.4	95.9	7.8	295.9	3.0
Acenaphthene	7.8	15.7	1.3	51.2	0.0
Phenanthrene	77.2	90.0	10.6	293.8	11.2
Fluorene	30.8	43.1	3.6	144.9	2.6
A-Methylfluorene	5.3	8.6	1.7	27.6	-0.9
1-Methylfluorene	6.1	7.8	1.1	26.2	0.5
B-Methylfluorene	2.0	2.7	0.4	9.2	0.2
C-Methylfluorene	55.5	53.8	8.0	166.0	5.4
A-Methylphenanthrene	8.7	13.3	2.0	44.7	0.7
2-Methylphenanthrene	9.3	13.9	1.7	46.6	0.8
B-Methylphenanthrene	2.6	5.4	0.6	17.7	0.1
C-Methylphenanthrene	3.0	5.0	0.9	16.5	0.0
1-Methylphenanthrene	5.1	7.7	1.0	26.1	0.2
3,6-Dimethylphenanthrene	1.8	3.1	0.6	10.4	-0.1
A-Dimethylphenanthrene	2.4	4.5	0.7	14.9	-0.1
B-Dimethylphenanthrene	1.2	2.4	0.4	7.9	-0.1
C-Dimethylphenanthrene	3.0	6.3	0.8	20.5	-0.4
1,7-Dimethylphenanthrene	2.2	4.6	0.5	15.1	-0.1
D-Dimethylphenanthrene	1.1	2.3	0.5	7.4	-0.1
E-Dimethylphenanthrene	1.5	3.0	0.4	9.8	-0.1
Anthracene	17.7	25.4	3.0	84.5	2.1
9-Methylanthracene	0.4	0.6	0.3	2.0	0.0
Fluoranthene	35.1	44.4	7.4	149.0	1.9
Pyrene	43.6	56.9	9.1	194.5	1.1
A-Methylpyrene	0.0	0.0	0.2	0.0	0.0
B-Methylpyrene	1.9	2.8	0.4	9.6	0.3
C-Methylpyrene	3.7	5.7	0.8	19.5	0.3
D-Methylpyrene	1.8	3.0	0.4	10.1	0.2
E-Methylpyrene	1.4	2.0	0.4	6.9	0.1
F-Methylpyrene	0.8	1.4	0.3	4.5	-0.1
Retene	0.0	0.1	0.3	0.1	-0.1
Benzonaphthothiophene	0.1	0.1	0.4	0.4	0.0
Benz(a)anthracene	1.2	1.7	0.8	5.9	0.1
7-Methylbenz[a]anthracene	0.1	0.1	0.2	0.3	0.0
Chrysene	1.6	1.9	0.5	6.7	0.3
Benzo(b+j+k)fluoranthene	2.3	4.7	0.7	15.1	-0.2
Benzo(e)pyrene	1.1	2.0	0.4	6.3	-0.1
Benzo(a)pyrene	0.9	1.8	0.7	5.8	0.0
7-Methylbenzo[a]pyrene	0.1	0.2	0.2	0.7	0.0
Indeno[1,2,3-cd]pyrene	0.6	1.2	0.7	3.8	-0.1
Dibenz(ah+ac)anthracene	0.1	0.1	0.8	0.3	0.0
Benzo(b)chrysene	0.0	0.1	0.4	0.2	0.0
Benzo(ghi)perylene	2.3	4.4	0.9	13.4	-0.1
Coronene	1.9	4.4	0.9	12.9	-0.4

Note: Bold numbers indicate averages that are at least twice the average uncertainty

Capital Letters in front of PAHs indicate cases where the exact configuration of methyl groups is not known

Table 19. Organic Carbon and PAHs for Phase 2 Test Vehicles

		Organic Carbon ($\mu\text{g}/\text{mi}$)	Total PAH ($\mu\text{g}/\text{mi}$)	Particle PAH ($\mu\text{g}/\text{mi}$)	Semi-Volatile PAH ($\mu\text{g}/\text{mi}$)
1994 Dodge	Shadow	330	63.1	42.3	20.9
1990 Nissan	Sentra	1,130	1164.6	473.4	691.2
1990 Ford	Tempo	480	146.7	65.7	81
1989 Toyota	Celica	90	172.8	90.3	82.6
1987 Acura	Integra	2,200	908.2	429.1	479.1
1987 Buick	Park Avenue	710	205.8	108.2	97.6
1985 Oldsmobile	Cutlass	2,390	485.5	87.9	397.6
1984 Mazda	626	18,780	7,386	1,457	5,929
1980 Honda	Prelude	4,820	1313.5	183.0	1,130.4
1979 Plymouth	Horizon	66,130	3419.1	438.8	2,980.3

Table 20. Percent of Particulate Mass less than 10.0, 2.5, and 1.0 μm

Category	Percent Less Than		
	10 μm	2.5 μm	1.0 μm
1986+	96.0%	91.3%	84.6%
1981-1985	95.4%	89.4%	82.5%
1975-1980	97.7%	94.1%	88.8%
Pre-1975	96.1%	89.2%	82.6%

5.0 SUMMARY AND CONCLUSIONS

5.1 Phase 1 Conclusions

The following conclusions can be drawn from results of Phase 1 of this study:

- All vehicle technologies showed a statistically significant effect of higher particulate emissions on the UC than the FTP. This effect was largest in an absolute and relative basis for the oxidation and non-catalyst technologies.
- The effects of driving cycle on gaseous emissions are generally less than the effect on particulate emissions. Consistent and statistically significant trends of increased gaseous emissions over the UC were observed for the oxidation catalyst and non-catalyst vehicle, but not for the TWC vehicle.
- Fuel composition had a smaller effect on particulate emissions than driving cycle and varied between vehicle technologies and different bags of the driving cycles.
- For the non-catalyst vehicle, RFG produced lower overall particulate emissions than the pre-1992 fuel.
- For the oxidation catalyst vehicle, the particulate emissions results varied for different phases. Particulate emissions were higher for pre-1992 gasoline for bag 1 and lower for bag 2. This result may be attributable to preconditioning effects, however.
- For the TWC vehicle, fuel differences had essentially no effect on particulate emissions with the possible exception of bag 1 emissions.
- RFG resulted in a trend of lower THC, CO, and NO_x emissions for the oxidation catalyst vehicle and lower THC and CO emissions for the non-catalyst vehicle. The effects on gaseous emissions of TWC vehicle were varied and may have been affected by vehicle repeatability.
- The chemical breakdowns show that elemental and organic carbon are the primary constituents of gasoline exhaust particulate. Inorganic species comprise a smaller portion of the total particulate and include sulfate, elemental Si and S.
- Sulfate and other ions make a relatively small contribution to the total particulate.
- Lower percentages of organic carbon relative to elemental carbon are observed for the catalyst-equipped Ford Tempo and Datsun compared with the non-catalyst Ford Mustang.
- The overall mass emission rates for inorganic species are relatively consistent from vehicle to vehicle. On a percentage basis, inorganic species compose a larger fraction of the total particulate matter for the catalyst-equipped vehicles with lower mass emission rates.
- Overall, the particulate composition was not strongly fuel-dependent; although there is some evidence that fuel may affect the organic fraction of the particulate. The organic

fraction for all three vehicles was higher on RFG than on pre-1992 gasoline. This result, however, was statistically significant only for the Datsun. The effect of fuel on the particulate emissions of ions and elements was relatively minor.

- Driving cycle did not have a significant impact on the organic-to-elemental fractions of the particulate. The combined emissions of all ions and elements were higher for the UC than the FTP for all three test vehicles. This is consistent with the overall higher particulate emissions observed for the more aggressive UC.
- Although some differences were observed between different bags for elemental and organic carbon for different vehicles and cycles, none of these differences was statistically significant. Combined emissions of all elements and ions were higher for the Datsun for bag 2 of the UC than for bags 1 and 3. This can probably be attributed to the more aggressive nature of bag 2 of the UC.

5.2 Phase 2 - Conclusions

The following conclusions can be drawn from results of Phase 2 of this study:

- UC particulate mass emission rates from 1986+ model year gasoline vehicles are low (<5 mg/mi) but increase with age.
- Particulate emissions for Bag 1 of the UC are the highest. Particulate emissions for Bags 2 and 3 are comparable.
- Vehicle conditioning appears to be an important issue in measuring particulate emissions on aggressive cycles such as the UC. On 16 of the 24 vehicles tested in Phase 2, bag 2 emissions declined by at least 25% between the initial test(s) and the replicates. Similar effects have been reported in previous studies. Together, these data indicate that vehicle preconditioning and repeatability are important issues to address and merit further investigation in future work.
- Average NMHC, CO, and NO_x emissions for gasoline all increase with vehicle age, consistent with the particulate emission results.
- Elemental and organic carbon were the primary constituents for the particulate. On a vehicle average basis, organic carbon represented the larger fraction of the two. The contribution of organic carbon was generally larger for the older, higher-emitting vehicles.
- Inorganic species, including ions and trace elements, composed an average of 12.9% of the total mass. The most prominent chemical species were Fe, Si, SO₄²⁻, Ca, and Zn.
- The contribution of organic carbon needs to be added to the ARB's source profile for gasoline vehicles. The levels of sulfate found in this work are substantially less than those currently being used in the ARB's source profile, however.

- Total PAH emissions rates averaged 1,527 µg/mi for the gasoline vehicles, with a range from 63 to 7,386. The distribution of PAHs was similar to that reported previously, with naphthalene, methylnaphthalene, and dimethylnaphthalene being primary constituents. Other PAHs identified include acenaphthylene, phenanthrene, methylfluorene, fluorene, and pyrene.
- Hopane or sterane compounds were, for the most part, not measured at levels above twice the average analytical uncertainty. Since hopanes and steranes are primarily oil tracers, this indicates that excessive oil burning did not make a significant contribution to the particulate composition for any of the 10 vehicles analyzed. This result also suggests that hopanes and steranes are of limited use in developing source profiles for gasoline vehicles, since their emissions are significant for only a portion of the gasoline fleet vehicles.

6.0 RECOMMENDATIONS

Based on the results of this study, the following recommendations are made:

Further studies comparing particulate emissions for the FTP and more aggressive driving cycles such as the UC and US06 are needed. This work should include a larger and more representative sample of vehicles, and include light-duty trucks.

More extensive studies of the affects of driving cycle and vehicle operating mode should be conducted using real-time particulate sampling techniques such as a condensation particle counter or spectrophone.

Additional studies are needed to develop and assess procedures for obtaining repeatable particulate emissions measurements over more aggressive driving cycles. These studies should include measurement of particulate mass emissions, chemical composition and size distributions.

The ARB's source profile for gasoline vehicles should be updated to include organic carbon, while the sulfate contribution should be reduced substantially.

To obtain more accurate source profiles, data on particulate composition for larger fleets of vehicles is needed. These measurements should include elemental and organic carbon and PAHs.

Further studies of fuel effects on particulate emissions should include more replicate testing on a specific cycle for statistical verification and larger numbers of vehicles. For mass emissions, the more significant differences will probably be observed during the cold start or for older vehicles. Chemical analyses measurements should be expanded to include PAH emissions, since there is some evidence from this study that fuel may affect the organic fraction of the particulate.

Measurements of the chemical composition and PAH and nitro-PAH profiles should be obtained as a function of particle size. Such information would further our understanding of gas-to-particle conversion and the mechanisms of particle dynamics and PAH-particle association.

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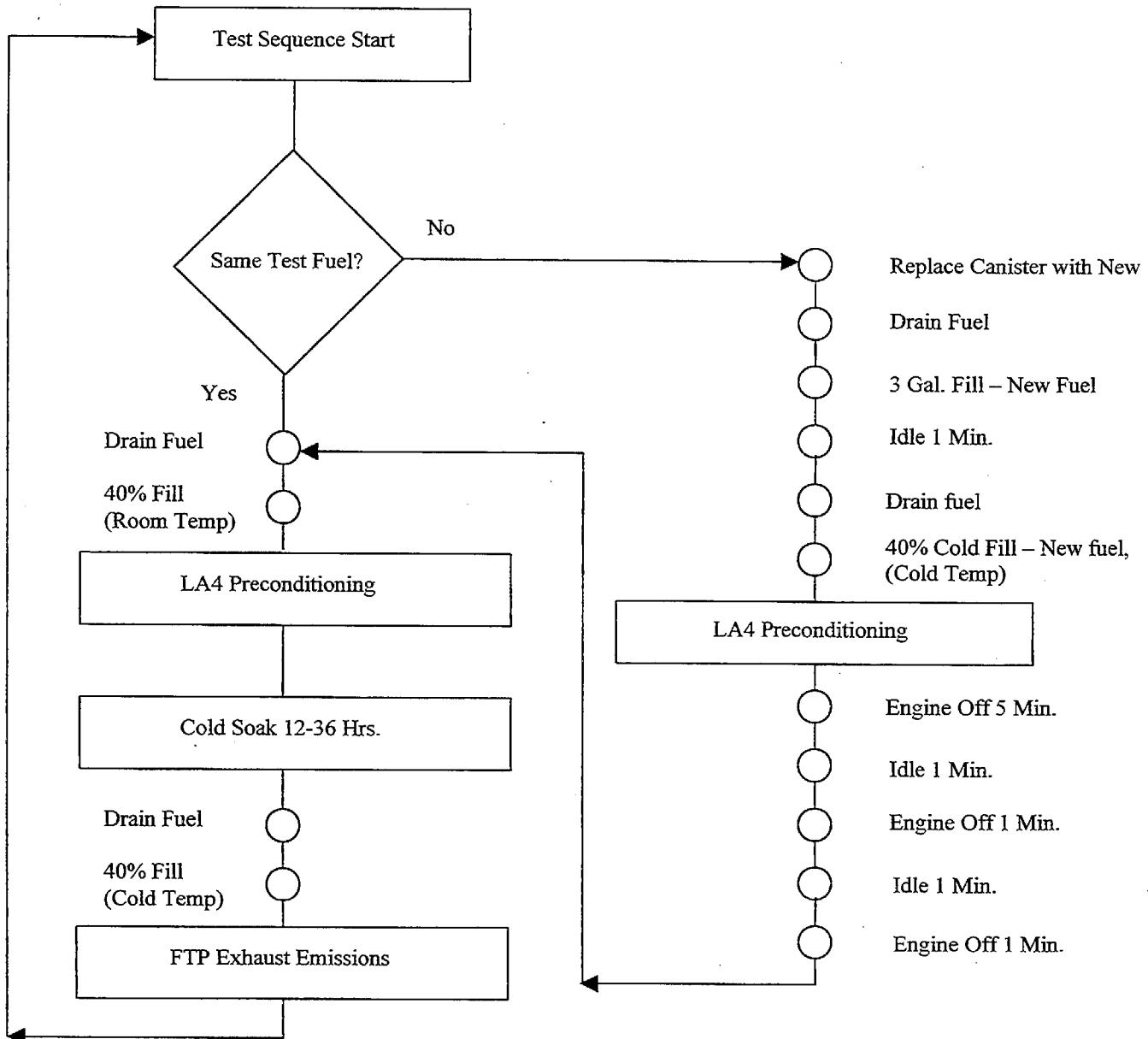
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Appendix A. Vehicle Refueling and Preconditioning Procedures



Appendix B. Gaseous and Particulate Results for Phase 1

Table B-1. Gaseous and Particulate Mass Emissions Results for FTP/UIC Tests For 1990 Ford Temp⁰

Cycle/Fuel	Date	Bag 1			Bag 2			Bag 3			FTP Weighted					
		THC	NMHC	NO _x	CO	Parts.	THC	NMHC	NO _x	CO	Parts.	THC	NMHC	NO _x	CO	Parts.
					mg/mi				mg/mi		mg/mi				mg/mi	
<i>FTP/Calif. Phase 2</i>																
Test # H9607043	7/23/96	0.71	0.62	0.61	14.22	1.75†	0.16	0.08	0.16	4.06	1.23†	0.18	0.12	0.41	3.71	0.96†
Test # H9607047	7/24/96	0.81	0.72	0.55	13.64		0.11	0.05	0.15	3.50		0.16	0.11	0.46	3.28	
Test # H9607053	7/25/96	0.73	0.64	0.59	14.14		0.16	0.07	0.14	4.85		0.18	0.12	0.39	3.81	
Test # H9607063	7/30/96	0.64	0.56	0.61	11.90		0.14	0.07	0.14	3.92		0.24	0.17	0.42	3.99	
Test # H9607036*	7/16/96											1.04				
Test # H9607040*	7/17/96											0.97				
Test # H9607042*	7/18/96											1.23				
Test # H9607044*	7/23/96											1.50				
Test # H9607048*	7/24/96											1.85				
Test # H9607064*	7/30/96											0.93				
Average		0.72	0.63	0.59	13.48		0.14	0.07	0.15	4.08	1.25	0.19	0.13	0.42	3.70	0.96†
Standard Deviation		0.07	0.07	0.03	1.08		0.02	0.02	0.01	0.57	0.33	0.03	0.03	0.30	0.01	0.01
Coeff. of Variation (%)		9.7	10.4	5.2	8.0		15.8	22.2	6.7	13.9	26.3	17.3	22.2	6.8	8.2	2.5
<i>FTP/Calif. pre-1992</i>																
Test # H9611032	11/14/96	0.73	0.66	0.81	10.32	3.09†	0.12	0.06	0.17	3.02	1.74†	0.19	0.14	0.41	2.96	0.81†
Test # H9611036	11/15/96	1.44	1.32	0.48	28.23		0.11	0.06	0.15	3.26		0.16	0.12	0.36	2.66	0.40
Test # H9611029*	11/13/96											1.22				
Test # H9611029*	11/13/96											1.04				
Average		1.08	0.99	0.65	19.28		0.12	0.06	0.16	3.14	1.33	0.18	0.13	0.39	2.81	0.33
Standard Deviation		0.50	0.47	0.23	12.66		0.00	0.00	0.02	0.17	0.36	0.02	0.04	0.21	0.10	0.09
Coeff. of Variation (%)		46.4	47.2	35.9	65.7		4.3	2.4	10.3	5.3	27.3	13.3	14.6	9.3	7.5	28.7
																33.4
																20.6
																41.5

Note: All gaseous emissions reported in g/mi

† Particulate Sample Collected over 2-4 FTP cycles

* Replicate bag 2 test

Table B-1. Continued - Gaseous and Particulate Mass Emissions Results for FTP/UC Tests For 1990 Ford Tempo

Cycle/Fuel	Date	Bag 1						Bag 2						Bag 3						Weighted		
		THC	NMHC	NO _x	CO	Parts.		THC	NMHC	NO _x	CO	Parts.	THC	NMHC	NO _x	CO	Parts.	THC	NMHC	NO _x	CO	Parts.
<i>UC/Calif. Phase 2</i>																						
Test # H9611008	11/5/96	2.26	2.10	1.90	22.19	3.17†	0.09	0.05	0.41	3.13	3.16‡	0.24	0.16	0.56	3.17	1.27‡	0.21	0.16	0.50	4.13	3.03‡	
Test # H9611010	11/6/96	1.78	1.64	1.96	22.21		0.08	0.04	0.50	3.25		0.23	0.15	0.89	3.94		0.18	0.13	0.61	4.29		
Test # H9611014	11/7/96	1.90	1.75	1.84	23.85		0.05	0.02	0.40	1.87		0.20	0.12	0.69	3.22		0.16	0.12	0.49	3.11		
Test # H9611015*	11/7/96						0.08	0.05	0.43	2.68	1.35											
Test # H9611015*	11/7/96						0.05	0.02	0.44	2.71	2.12											
Test # H9607035	7/16/96	1.87	1.72	1.5	17.03		0.11	0.06	0.33	4.04		0.27	0.18	0.60	3.96		0.21	0.16	0.41	4.71	5.16 ^a	
Test # H9607039	7/17/96	1.96	1.76	1.52	31.03		0.14	0.09	0.43	5.83		0.40	0.26	0.58	7.87		0.25	0.19	0.50	7.29		
Test # H9607041	7/18/96	2.11	1.91	1.2	33.86		0.13	0.08	0.43	5.36		0.36	0.25	0.71	6.62		0.25	0.19	0.49	6.94		
Average		1.98	1.81	1.65	25.03		0.09	0.05	0.42	3.61	2.21	0.28	0.18	0.67	4.80		0.21	0.16	0.50	5.08		
Standard Deviation		0.18	0.17	0.29	6.25		0.03	0.02	0.05	1.38	0.91	0.08	0.06	0.12	1.97		0.04	0.03	0.06	1.67		
Coeff. Of Variation (%)		8.9	9.1	17.8	25.0		36.6	45.9	11.4	38.1	41.1	27.8	31.4	18.1	41.0		17.6	16.7	12.6	32.8		
<i>UC/Calif. pre-1992</i>																						
Test # H9611050	11/21/96	1.68	1.55	2.00	19.80	5.83‡	0.12	0.08	0.50	4.63	2.20‡	0.30	0.21	0.46	6.87	1.26‡	0.21	0.16	0.57	5.58	2.33‡	
Test # H9612007	12/4/96	1.87	1.76	2.11	17.29		0.11	0.07	0.46	4.23		0.25	0.17	0.56	6.13		0.21	0.17	0.55	5.04		
Test # H9612011	12/5/96	1.76	1.65	2.22	20.13		0.14	0.10	0.40	5.25		0.21	0.14	0.58	4.24		0.23	0.18	0.51	5.96		
Test # H9611051*	11/21/96																					
Test # H9611051*	11/21/96																					
Average		1.77	1.65	2.11	19.07		0.14	0.09	0.45	5.53	2.28	0.25	0.17	0.53	5.74		0.21	0.17	0.54	5.53		
Standard Deviation		0.09	0.10	0.11	1.55		0.02	0.02	0.05	1.34	0.62	0.05	0.04	0.06	1.35		0.01	0.01	0.03	0.46		
Coeff. Of Variation (%)		5.3	6.2	5.3	8.1		18.3	20.3	10.6	24.3	27.1	18.5	21.7	12.2	23.6		4.4	5.4	6.3	8.3		

Note: All gaseous emissions reported in g/mi.

† Particulate Sample Collected over 3 Unified Cycles

a cumulative sample over 3 Unified Cycles - unweighted

* Replicate bag 2 test

Unified Cycle Weighted Emissions = $0.43((\text{Mass Emissions Bag 1} + \text{Mass Emissions Bag 2}) / (\text{Distance Bag 1} + \text{Distance Bag 2})) + 0.57((\text{Mass Emissions Bag 3} + \text{Mass Emissions Bag 2}) / (\text{Distance Bag 3} + \text{Distance Bag 2}))$

Table B-2. Gaseous and Particulate Mass Emissions Results for FTP/UC Tests For 1981 Datsun 310

Cycle/Fuel	Date	Bag 1				Bag 2				Bag 3				Weighted Parts. mg/mi	CO Parts. mg/mi	NO _x Parts. mg/mi	CO Parts. mg/mi	NO _x Parts. mg/mi	THC Parts. mg/mi	NMHC Parts. mg/mi	THC
		THC	NMHC	NO _x	CO	THC	NMHC	NO _x	CO	THC	NMHC	NO _x	CO								
<i>FTP/Calif. Phase 2</i>																					
Test # H9612038	12/17/96	1.34	1.14	1.97	26.29	8.44	0.16	0.48	0.53	2.97	0.27	0.21	1.04	1.69	1.42	0.43	0.35	0.94	6.17	3.68	
Test # H9612039*	12/17/96					0.16	0.11	0.45	0.36	1.26											
Test # H9612039*	12/17/96					0.16	0.11	0.45	0.29	1.05											
Average						0.16	0.10	0.46	0.39	1.76											
Standard Deviation						0.00	0.00	0.02	0.13	1.05											
Coeff. of Variation (%)						1.3	3.1	3.9	32.2	59.8											
<i>FTP/Calif. pre-1992</i>																					
Test # H9612046	12/19/96	1.71	1.49	2.34	32.00	23.15	0.16	0.11	0.60	1.01	0.77	0.28	0.23	1.10	2.54	1.62	0.51	0.42	1.10	7.82	5.61
Test # H9612047*	12/19/96					0.16	0.11	0.53	0.89	0.55											
Test # H9612047*	12/19/96					0.16	0.10	0.51	0.59	0.61											
Average						0.16	0.11	0.55	0.83	0.64											
Standard Deviation						0.00	0.01	0.05	0.22	0.11											
Coeff. of Variation (%)						2.2	6.1	9.0	26.1	17.7											
<i>UC/Calif. Phase 2</i>																					
Test # H9612042	12/18/96	6.15	5.21	3.12	84.81	56.81	0.21	0.14	1.64	3.26	17.55	0.46	0.39	2.01	4.06	2.40	0.54	0.42	1.75	7.61	18.56
Test # H9612043*	12/18/96					0.21	0.16	1.32	2.40	19.15											
Test # H9612043*	12/18/96					0.18	0.13	1.27	1.96	15.47											
Average						0.20	0.14	1.41	2.54	17.39											
Standard Deviation						0.02	0.02	0.20	0.66	1.85											
Coeff. of Variation (%)						9.1	10.7	14.4	26.0	10.6											
<i>UC/Calif. pre-1992</i>																					
Test # H9612051	12/20/96	8.09	7.21	3.16	91.14	102.04	0.22	0.16	1.81	3.45	10.90	0.50	0.42	2.08	3.90	1.89	0.66	0.55	1.90	8.11	15.08
Test # H9612052*	12/20/96					0.21	0.15	1.49	1.92	6.38											
Test # H9612052*	12/20/96					0.18	0.13	1.41	1.84	12.88											
Average						0.20	0.15	1.57	2.40	10.05											
Standard Deviation						0.02	0.01	0.21	0.90	3.33											
Coeff. of Variation (%)						9.6	9.7	13.7	37.6	33.1											

All gaseous emissions reported in g/mi; * Replicate bag 2 test

Table B-3. Gaseous and Particulate Mass Emissions Results for FTP/UC Tests For 1967 Ford Mustang

Cycle/Fuel	Date	Bag 1						Bag 2						Bag 3						Weighted Parts. mg/mi	
		THC	NMHC	NO _x	CO	Parts. mg/mi		THC	NMHC	NO _x	CO	Parts. mg/mi		THC	NMHC	NO _x	CO	Parts. mg/mi			
<i>FTP/Calif. Phase 2</i>																					
Test # H9612025	12/11/96	4.35	4.02	1.38	106.48	13.13	3.47	3.20	0.82	85.42	5.50	3.70	3.40	1.12	97.68	17.06	3.72	3.43	1.02	93.13	10.25
Test # H9612014*	12/5/96							3.32	3.10	0.97	72.06	8.88									
Test # H9612014*	12/5/96							3.30	3.10	1.05	62.67	8.84									
Average								3.36	3.14	0.94	73.38	7.74									
Standard Deviation								0.10	0.06	0.12	11.43	1.94									
Coeff. of Variation (%)								2.8	1.8	12.4	15.6	25.1									
<i>FTP/Calif. Pre-1992</i>																					
Test # H9612029	12/12/96	4.59	4.26	1.28	118.91	16.34	3.79	3.49	0.75	104.58	10.49	4.27	3.92	0.96	118.81	24.93	4.09	3.77	0.92	111.44	15.66
Test # H9612030*	12/12/96							3.70	3.43	0.85	97.39	12.34									
Test # H9612030*	12/12/96							3.70	3.43	0.94	95.48	14.24									
Average								3.73	3.45	0.85	99.15	12.36									
Standard Deviation								0.05	0.04	0.10	4.80	1.88									
Coeff. of Variation (%)								1.3	1.1	11.5	4.8	15.2									
<i>UC/Calif. Phase 2</i>																					
Test # H9612022	12/10/96	8.40	7.75	1.45	181.76	13.86	4.37	3.97	1.47	133.10	36.68	5.74	5.36	1.42	117.01	8.44	4.67	4.27	1.47	134.54	33.52
Test # H9612016*	12/6/96							4.22	3.83	1.22	122.73	43.74									
Test # H9612016*	12/6/96							4.37	3.97	1.23	123.21	47.72									
Average								4.32	3.92	1.31	126.35	42.71									
Standard Deviation								0.09	0.08	0.15	5.85	5.59									
Coeff. of Variation (%)								2.0	2.0	11.2	4.6	13.1									
<i>UC/Calif. Pre-1992</i>																					
Test # H9612033	12/13/96	9.25	8.62	1.74	190.55	26.39	4.71	4.29	1.28	148.23	66.06	7.23	6.55	1.19	162.69	42.71	5.13	4.68	1.30	151.45	62.37
Test # H9612034*	12/13/96							4.57	4.15	1.05	146.18	57.74									
Test # H9612034*	12/13/96							4.83	4.36	0.98	155.69	68.21									
Average								4.71	4.27	1.10	150.03	64.00									
Standard Deviation								0.13	0.11	0.15	5.00	5.53									
Coeff. of Variation (%)								2.8	2.5	14.0	3.3	8.6									

All gaseous emissions reported in g/mi; * Replicate bag 2 test

Appendix C. Statistical Summary of the Driving Cycle Effects for Phase 1

**Table C-1. Statistical Summary of the Driving Cycle Effects
for Ford Mustang and Datsun 310
(Based on Bag 2 Results)**

Datsun 310

Cycle	Particles		THC		NO _x		CO	
	FTP	UC	FTP	UC	FTP	UC	FTP	UC
Mean	1.76	17.39	0.16	0.20	0.46	1.41	0.39	2.54
% change		+888		+25.0		+207		+551
p-value	<u>0.0002</u>		<u>0.0258</u>		<u>0.0013</u>		<u>0.0052</u>	

Cycle Effects for Pre-1992 California average gasoline

Cycle	THC		NO _x		CO	
	FTP	UC	FTP	UC	FTP	UC
Mean	0.64	10.05	0.16	0.20	0.55	1.57
% change		+1470		+25.0		+185
p-value	<u>0.0081</u>		<u>0.0173</u>		<u>0.0013</u>	

Ford Mustang

Cycle	Particles		THC		NO _x		CO	
	FTP	UC	FTP	UC	FTP	UC	FTP	UC
Mean	7.74	42.71	3.36	4.32	0.94	1.31	73.38	126.35
% change		+452		+28.6		+39.4		+53.0
p-value	<u>0.0005</u>		<u>0.0002</u>		<u>0.0283</u>		<u>0.0020</u>	

Cycle	Particles		THC		NO _x		CO	
	FTP	UC	FTP	UC	FTP	UC	FTP	UC
Mean	12.36	64.00	3.73	4.71	0.85	1.10	99.15	150.03
% change		+418		+26.3		+29.4		+51.3
p-value	<u>0.0001</u>		<u>0.0003</u>		<u>0.0727</u>		<u>0.0002</u>	

Underlined p-values are statistically significant at the 95% confidence level

Table C-2. Statistical Summary of the Driving Cycle Effects for Ford Tempo

		California Phase 2 gasoline							
		Particles		THC		NO _x		CO	
Cycle		FTP	UC	FTP	UC	FTP	UC	FTP	UC
Bag 1	Average	1.75*	3.17*	0.72	1.98	0.59	1.65	13.48	25.03
	% change		+81.1		+175		+180		+85.7
	p-value			<u>0.0001</u>		<u>0.0001</u>		<u>0.0071</u>	
Bag 2	Average	1.25	2.21	0.14	0.09	0.15	0.42	4.08	3.61
	% change		+76.8		-35.7		+180		-11.5
	p-value	<u>0.0318</u>		<u>0.0188</u>		<u>0.0001</u>		0.5298	
Bag 3	Average	0.96*	1.27*	0.19	0.28	0.42	0.67	3.70	4.80
	% change		+32.3		+47.4		+59.5		+29.7
	p-value			0.0610		<u>0.0041</u>		0.3076	
Weighted	Average	1.27*	3.03*	0.28	0.21	0.31	0.50	5.92	5.08
	% change		+138.5		-25.0		+61.3		-14.2
	p-value			<u>0.0088</u>		<u>0.0004</u>		0.3602	

		Pre-1992 California average gasoline							
		Particles		THC		NO _x		CO	
Cycle		FTP	UC	FTP	UC	FTP	UC	FTP	UC
Bag 1	Average	3.09*	5.83*	1.08	1.77	0.65	2.11	19.28	19.07
	% change		+88.7		+63.9		+225		-1.1
	p-value			0.0883		<u>0.0022</u>		0.9782	
Bag 2	Average	1.33	2.28	0.12	0.14	0.16	0.45	3.14	5.53
	% change		+71.4		+16.7		+181		+76.1
	p-value	0.0837		0.3371		<u>0.0005</u>		0.0639	
Bag 3	Average	0.81*	1.26*	0.18	0.25	0.39	0.53	2.81	5.74
	% change		+55.6		+38.9		+35.9		+104
	p-value			0.1362		0.0667		0.0632	
Weighted	Average	1.76*	2.33*	0.33	0.21	0.32	0.54	6.39	5.53
	% change		+32.4		-36.4		+68.8		-13.5
	p-value			0.1025		<u>0.0145</u>		0.5911	

Underlined p-values are statistically significant at the 95% confidence level

* single test iteration

Appendix D. Statistical Summary of the Fuel Effects for Phase 1

**Table D-1. Statistical Summary of the Fuel Effects
for Ford Mustang and Datsun 310
(Based on Bag 2 Results)**

Ford Mustang

Fuel	Particles		THC		NO _x		CO	
	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2
Mean	12.36	7.74	3.73	3.36	0.85	0.94	99.15	73.38
% change		-37.4		-9.9		+10.6		-26.0
p-value	<u>0.0414</u>		<u>0.0041</u>		0.3357		<u>0.0227</u>	

Fuel Effects for UC

Fuel	Particles		THC		NO _x		CO	
	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2
Mean	64.00	42.71	4.71	4.32	1.10	1.31	150.03	126.35
% change		-33.3		-8.3		+19.1		-15.8
p-value	<u>0.0094</u>		<u>0.0134</u>		0.1740		<u>0.0060</u>	

Datsun 310

Fuel Effects for FTP

Fuel	Particles		THC		NO _x		CO	
	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2
Mean	0.64	1.76	0.16	0.16	0.55	0.46	0.83	0.39
% change		+175		-0.0		-16.4		-53.0
p-value	0.1419		0.4439		<u>0.0485</u>		<u>0.0390</u>	

Fuel Effects for UC

Fuel	Particles		THC		NO _x		CO	
	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2
Mean	10.05	17.39	0.20	0.20	1.57	1.41	2.40	2.54
% change		+73.0		-0.0		-10.2		+5.8
p-value	<u>0.0289</u>		0.6716		0.4037		0.8429	

Underlined p-values are statistically significant at the 95% confidence level

Table D-2. Statistical Summary of the Fuel Effects for the Ford Tempo

Fuel	Particles		FTP		NO _X		CO	
	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2
Bag 1	Average	3.09*	1.75*	1.08	0.72	0.65	0.59	19.28
	% change		-43.4		-33.3		-9.2	-30.1
	p-value			0.1792		0.6000		0.3546
Bag 2	Average	1.33	1.25	0.12	0.14	0.16	0.15	3.14
	% change		-6.0		+16.7		-6.3	+4.08
	p-value	0.7299		0.1842		0.2547		0.0938
Bag 3	Average	0.81*	0.96*	0.18	0.19	0.39	0.42	2.81
	% change		+18.5		+5.6		+7.7	+3.70
	p-value			0.5828		0.2677		<u>0.0225</u>
Weighted	Average	1.76*	1.27*	0.33	0.28	0.32	0.31	6.39
	% change		-27.8		-15.2		-3.1	-5.92
	p-value			0.2430		0.7583		0.7157

Fuel	Particles		FTP		NO _X		CO	
	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2	Pre-1992	Phase 2
Bag 1	Average	5.83*	3.17*	1.77	1.98	2.11	1.65	19.07
	% change		-45.6		+11.9		-21.8	+25.03
	p-value			0.0996		<u>0.0398</u>		0.1594
Bag 2	Average	2.28	2.21	0.14	0.09	0.45	0.42	5.52
	% change		-3.1		-35.7		-6.7	3.61
	p-value	0.9136		<u>0.0259</u>		0.3051		<u>0.0313</u>
Bag 3	Average	1.26*	1.27*	0.25	0.28	0.53	0.67	5.74
	% change		+0.8		+12.0		+26.4	4.80
	p-value			0.5176		0.1146		0.4844
Weighted	Average	2.33*	3.03*	0.21	0.21	0.54	0.50	5.53
	% change		+30.0		0.0		-7.4	-5.08
	p-value			0.8362		0.3122		0.6711

Underlined p-values are statistically significant at the 95% confidence level

* single test iteration

Appendix E. Chemical Mass Emission Results for Phase 1

Table E-1. Chemical Mass Emissions Rates for Ford Tempo

Cycle	FTP						
Fuel	California Phase 2						
Test #	H9607043,7047,7053,7063						
Bag	Bag 1		Bag 2		Bag 3		Weighted
Mass Em. Rate (mg/mi)	1.75		1.23		0.96		1.27
Cl ⁻	0.0107	+/- 0.0123	0.0067	+/- 0.0112	0.0150	+/- 0.0162	0.0098 +/- 0.0078
NO ₃ ⁻	-0.0104	+/- 0.0082	-0.0111	+/- 0.0080	0.0082	+/- 0.0097	-0.0057 +/- 0.0052
(SO ₄) ²⁻	0.0368	+/- 0.0091	0.0093	+/- 0.0079	0.0475	+/- 0.0108	0.0254 +/- 0.0054
NH ₄ ⁺	-0.0069	+/- 0.0173	0.0024	+/- 0.0168	0.0361	+/- 0.0210	0.0097 +/- 0.0110
OC	0.5230	+/- 0.1033	0.3319	+/- 0.0913	0.2556	+/- 0.1045	0.3504 +/- 0.0594
EC	0.9296	+/- 0.0955	0.9886	+/- 0.1010	0.6795	+/- 0.0717	0.8917 +/- 0.0594
Na	-0.0029	+/- 0.0106	-0.0072	+/- 0.0100	0.0051	+/- 0.0041	-0.0029 +/- 0.0058
Mg	0.0127	+/- 0.0026	-0.0002	+/- 0.0047	0.0085	+/- 0.0028	0.0048 +/- 0.0026
Al	0.0028	+/- 0.0015	0.0004	+/- 0.0028	-0.0002	+/- 0.0032	0.0007 +/- 0.0017
Si	0.0257	+/- 0.0025	0.0364	+/- 0.0034	0.0241	+/- 0.0024	0.0309 +/- 0.0020
P	0.0107	+/- 0.0012	0.0005	+/- 0.0012	0.0057	+/- 0.0009	0.0040 +/- 0.0007
S	0.0176	+/- 0.0017	0.0133	+/- 0.0013	0.0152	+/- 0.0015	0.0147 +/- 0.0009
Cl	0.0037	+/- 0.0009	0.0039	+/- 0.0009	0.0031	+/- 0.0009	0.0036 +/- 0.0005
K	0.0000	+/- 0.0015	0.0004	+/- 0.0004	-0.0004	+/- 0.0012	0.0001 +/- 0.0005
Ca	0.0093	+/- 0.0010	0.0022	+/- 0.0006	0.0033	+/- 0.0007	0.0040 +/- 0.0004
Tl	0.0018	+/- 0.0053	0.0000	+/- 0.0055	0.0033	+/- 0.0061	0.0013 +/- 0.0035
V	0.0006	+/- 0.0022	0.0000	+/- 0.0022	0.0010	+/- 0.0025	0.0004 +/- 0.0014
Cr	0.0002	+/- 0.0005	0.0000	+/- 0.0005	0.0004	+/- 0.0006	0.0002 +/- 0.0003
Mn	0.0001	+/- 0.0004	0.0000	+/- 0.0004	0.0000	+/- 0.0005	0.0000 +/- 0.0003
Fe	0.0166	+/- 0.0015	0.0096	+/- 0.0009	0.0171	+/- 0.0016	0.0131 +/- 0.0007
Co	0.0000	+/- 0.0004	0.0001	+/- 0.0003	0.0002	+/- 0.0005	0.0001 +/- 0.0002
Ni	0.0005	+/- 0.0002	-0.0001	+/- 0.0003	0.0004	+/- 0.0002	0.0002 +/- 0.0002
Cu	0.0050	+/- 0.0005	0.0041	+/- 0.0004	0.0067	+/- 0.0006	0.0050 +/- 0.0003
Zn	0.0145	+/- 0.0013	0.0014	+/- 0.0002	0.0070	+/- 0.0007	0.0056 +/- 0.0003
Ga	0.0000	+/- 0.0004	0.0000	+/- 0.0004	0.0001	+/- 0.0005	0.0000 +/- 0.0003
As	0.0002	+/- 0.0005	0.0000	+/- 0.0005	0.0000	+/- 0.0006	0.0000 +/- 0.0003
Se	0.0000	+/- 0.0003	0.0000	+/- 0.0003	0.0002	+/- 0.0003	0.0001 +/- 0.0002
Br	0.0001	+/- 0.0002	0.0002	+/- 0.0003	0.0000	+/- 0.0003	0.0001 +/- 0.0002
Rb	0.0000	+/- 0.0002	0.0000	+/- 0.0002	0.0000	+/- 0.0002	0.0000 +/- 0.0001
Sr	0.0001	+/- 0.0002	0.0000	+/- 0.0003	0.0000	+/- 0.0003	0.0000 +/- 0.0002
Y	0.0000	+/- 0.0003	0.0000	+/- 0.0003	0.0000	+/- 0.0003	0.0000 +/- 0.0002
Zr	0.0003	+/- 0.0003	0.0003	+/- 0.0004	0.0003	+/- 0.0004	0.0003 +/- 0.0002
Mo	0.0006	+/- 0.0004	0.0008	+/- 0.0004	0.0014	+/- 0.0004	0.0009 +/- 0.0003
Pd	0.0000	+/- 0.0019	0.0004	+/- 0.0019	0.0000	+/- 0.0022	0.0002 +/- 0.0012
Ag	-0.0002	+/- 0.0022	0.0003	+/- 0.0022	-0.0002	+/- 0.0025	0.0000 +/- 0.0014
Cd	-0.0005	+/- 0.0022	0.0006	+/- 0.0023	0.0000	+/- 0.0026	0.0002 +/- 0.0015
In	0.0015	+/- 0.0026	0.0006	+/- 0.0027	0.0005	+/- 0.0030	0.0008 +/- 0.0017
Sn	0.0030	+/- 0.0020	0.0000	+/- 0.0034	0.0026	+/- 0.0039	0.0013 +/- 0.0021
Sb	0.0014	+/- 0.0040	0.0020	+/- 0.0041	0.0046	+/- 0.0025	0.0026 +/- 0.0024
Ba	0.0000	+/- 0.0147	0.0072	+/- 0.0151	0.0000	+/- 0.0170	0.0037 +/- 0.0096
La	0.0043	+/- 0.0193	0.0046	+/- 0.0199	0.0000	+/- 0.0225	0.0033 +/- 0.0127
Au	0.0000	+/- 0.0009	0.0000	+/- 0.0008	0.0000	+/- 0.0009	0.0000 +/- 0.0005
Hg	-0.0001	+/- 0.0006	0.0000	+/- 0.0006	0.0002	+/- 0.0006	0.0000 +/- 0.0004
Ti	0.0000	+/- 0.0005	0.0001	+/- 0.0006	0.0001	+/- 0.0006	0.0001 +/- 0.0004
Pb	0.0000	+/- 0.0007	0.0001	+/- 0.0008	0.0007	+/- 0.0005	0.0002 +/- 0.0005
U	0.0000	+/- 0.0005	0.0001	+/- 0.0006	0.0000	+/- 0.0006	0.0001 +/- 0.0004
Total	1.5895	+/- 0.1451	1.4002	+/- 0.1407	1.1222	+/- 0.1329	1.3630 +/- 0.0870
% Carbon	83.01%		107.35%		97.41%		97.80%
% Inorganic	7.82%		6.49%		19.48%		9.52%

Table E-1. Chemical Mass Emissions Rates for Ford Tempo (mg/mi)

Cycle	FTP							
Fuel	Pre-1992 California average gasoline							
Test #	H9611032,H9611036							
Bag	Bag 1		Bag 2		Bag 3		Weighted	
Mass Em. Rate (mg/mi)	3.09		1.74		0.81		1.76	
Cl ⁻	0.0264	+/- 0.0241	0.0147	+/- 0.0238	0.0158	+/- 0.0232	0.0174	+/- 0.0148
NO ₃ ⁻	0.0452	+/- 0.0139	0.0348	+/- 0.0127	0.0343	+/- 0.0132	0.0368	+/- 0.0080
(SO ₄) ²⁻	0.4849	+/- 0.0544	0.0199	+/- 0.0117	0.0700	+/- 0.0145	0.1294	+/- 0.0134
NH ₄ ⁺	0.5077	+/- 0.0688	0.0623	+/- 0.0283	0.0993	+/- 0.0297	0.1642	+/- 0.0220
OC	0.7285	+/- 0.1533	0.3606	+/- 0.1291	0.0364	+/- 0.1279	0.3475	+/- 0.0820
EC	1.7440	+/- 0.1764	1.5634	+/- 0.1592	0.6702	+/- 0.0728	1.3559	+/- 0.0926
Na	-0.0072	+/- 0.0143	-0.0025	+/- 0.0094	0.0040	+/- 0.0034	-0.0017	+/- 0.0058
Mg	0.0084	+/- 0.0029	0.0048	+/- 0.0023	0.0039	+/- 0.0062	0.0053	+/- 0.0022
Al	0.0045	+/- 0.0017	0.0039	+/- 0.0014	0.0019	+/- 0.0034	0.0035	+/- 0.0013
Si	0.0380	+/- 0.0036	0.0474	+/- 0.0044	0.0318	+/- 0.0031	0.0412	+/- 0.0025
P	0.0089	+/- 0.0011	0.0002	+/- 0.0014	0.0036	+/- 0.0008	0.0029	+/- 0.0008
S	0.0380	+/- 0.0035	0.0180	+/- 0.0017	0.0257	+/- 0.0024	0.0242	+/- 0.0013
Cl	0.0062	+/- 0.0011	0.0040	+/- 0.0009	0.0044	+/- 0.0010	0.0046	+/- 0.0006
K	0.0011	+/- 0.0005	0.0005	+/- 0.0004	0.0006	+/- 0.0018	0.0006	+/- 0.0005
Ca	0.0154	+/- 0.0015	0.0053	+/- 0.0007	0.0201	+/- 0.0020	0.0115	+/- 0.0007
Tl	0.0000	+/- 0.0061	0.0006	+/- 0.0059	0.0025	+/- 0.0061	0.0010	+/- 0.0037
V	0.0000	+/- 0.0025	0.0000	+/- 0.0034	0.0005	+/- 0.0025	0.0001	+/- 0.0020
Cr	0.0000	+/- 0.0006	0.0000	+/- 0.0010	0.0001	+/- 0.0006	0.0000	+/- 0.0006
Mn	0.0000	+/- 0.0005	0.0000	+/- 0.0005	0.0001	+/- 0.0005	0.0000	+/- 0.0003
Fe	0.0150	+/- 0.0014	0.0100	+/- 0.0009	0.0146	+/- 0.0013	0.0123	+/- 0.0007
Co	0.0000	+/- 0.0004	0.0000	+/- 0.0003	0.0000	+/- 0.0004	0.0000	+/- 0.0002
Ni	0.0000	+/- 0.0003	-0.0001	+/- 0.0003	0.0000	+/- 0.0003	0.0000	+/- 0.0002
Cu	0.0044	+/- 0.0004	0.0035	+/- 0.0004	0.0053	+/- 0.0005	0.0041	+/- 0.0003
Zn	0.0125	+/- 0.0011	0.0017	+/- 0.0002	0.0042	+/- 0.0004	0.0046	+/- 0.0003
Ga	0.0000	+/- 0.0005	0.0000	+/- 0.0004	0.0000	+/- 0.0005	0.0000	+/- 0.0003
As	0.0000	+/- 0.0006	0.0000	+/- 0.0005	0.0001	+/- 0.0006	0.0000	+/- 0.0003
Se	0.0000	+/- 0.0003	0.0001	+/- 0.0003	0.0000	+/- 0.0003	0.0000	+/- 0.0002
Br	0.0001	+/- 0.0003	0.0001	+/- 0.0003	0.0001	+/- 0.0003	0.0001	+/- 0.0002
Rb	0.0000	+/- 0.0003	0.0000	+/- 0.0002	0.0000	+/- 0.0002	0.0000	+/- 0.0001
Sr	0.0001	+/- 0.0003	0.0000	+/- 0.0003	0.0002	+/- 0.0003	0.0001	+/- 0.0002
Y	0.0000	+/- 0.0004	0.0000	+/- 0.0003	0.0000	+/- 0.0003	0.0000	+/- 0.0002
Zr	0.0004	+/- 0.0004	0.0003	+/- 0.0004	0.0003	+/- 0.0004	0.0003	+/- 0.0002
Mo	0.0005	+/- 0.0008	0.0004	+/- 0.0007	0.0007	+/- 0.0004	0.0005	+/- 0.0004
Pd	0.0000	+/- 0.0021	0.0003	+/- 0.0019	0.0000	+/- 0.0022	0.0002	+/- 0.0012
Ag	-0.0002	+/- 0.0025	0.0001	+/- 0.0022	-0.0002	+/- 0.0025	0.0000	+/- 0.0014
Cd	0.0007	+/- 0.0025	0.0001	+/- 0.0024	-0.0005	+/- 0.0026	0.0000	+/- 0.0015
In	0.0003	+/- 0.0030	-0.0001	+/- 0.0027	0.0012	+/- 0.0030	0.0003	+/- 0.0017
Sn	0.0021	+/- 0.0039	0.0011	+/- 0.0035	0.0012	+/- 0.0038	0.0014	+/- 0.0022
Sb	0.0000	+/- 0.0046	0.0004	+/- 0.0042	0.0040	+/- 0.0047	0.0013	+/- 0.0027
Ba	0.0083	+/- 0.0167	0.0009	+/- 0.0153	0.0033	+/- 0.0168	0.0031	+/- 0.0098
La	0.0000	+/- 0.0220	0.0067	+/- 0.0203	0.0044	+/- 0.0222	0.0047	+/- 0.0130
Au	0.0000	+/- 0.0010	0.0000	+/- 0.0008	0.0000	+/- 0.0008	0.0000	+/- 0.0005
Hg	-0.0001	+/- 0.0007	0.0001	+/- 0.0006	-0.0001	+/- 0.0006	0.0000	+/- 0.0004
Ti	0.0000	+/- 0.0006	0.0000	+/- 0.0006	0.0002	+/- 0.0006	0.0001	+/- 0.0004
Pb	0.0004	+/- 0.0009	-0.0001	+/- 0.0008	-0.0001	+/- 0.0008	0.0000	+/- 0.0005
U	0.0000	+/- 0.0006	0.0000	+/- 0.0006	0.0000	+/- 0.0006	0.0000	+/- 0.0004
Total	3.5065	+/- 0.2523	2.1422	+/- 0.2097	1.0250	+/- 0.1545	2.1171	+/- 0.1280
% Carbon	80.01%		110.57%		87.23%		96.78%	
% Inorganic	33.46%		12.54%		39.31%		23.51%	

Table E-1. Chemical Mass Emissions Rates for Ford Tempo (mg/mi)

Cycle	Unified Cycle								
Fuel	California Phase 2								
Test #	H9611008, H9611010, H9611014								
Bag	Bag 1		Bag 2		Bag 3		Weighted		
Mass Em. Rate (mg/mi)	3.17		3.16		1.27		3.03		
Cl ⁻	0.0204	+/- 0.0533	0.0254	+/- 0.0092	0.0053	+/- 0.0552	0.0238	+/- 0.0093	
NO ₃ ⁻	0.0848	+/- 0.0272	-0.0063	+/- 0.0070	-0.0280	+/- 0.0259	-0.0030	+/- 0.0066	
(SO ₄) ²⁻	0.0408	+/- 0.0254	0.0281	+/- 0.0075	0.0256	+/- 0.0262	0.0286	+/- 0.0070	
NH ₄ ⁺	0.0655	+/- 0.0557	0.0510	+/- 0.0162	0.0396	+/- 0.0574	0.0509	+/- 0.0151	
OC	1.0534	+/- 0.2920	0.8513	+/- 0.1153	0.2528	+/- 0.2792	0.8205	+/- 0.1042	
EC	1.8136	+/- 0.1928	1.1158	+/- 0.1132	0.9542	+/- 0.1156	1.1409	+/- 0.1003	
Na	-0.0030	+/- 0.0251	-0.0072	+/- 0.0077	0.0038	+/- 0.0191	-0.0062	+/- 0.0070	
Mg	0.0202	+/- 0.0049	0.0053	+/- 0.0022	0.0132	+/- 0.0039	0.0066	+/- 0.0019	
Al	0.0032	+/- 0.0065	0.0021	+/- 0.0014	-0.0001	+/- 0.0055	0.0020	+/- 0.0013	
Si	0.0486	+/- 0.0048	0.2966	+/- 0.0266	0.0355	+/- 0.0036	0.2657	+/- 0.0234	
P	0.0183	+/- 0.0020	0.0084	+/- 0.0009	0.0074	+/- 0.0012	0.0088	+/- 0.0008	
S	0.0175	+/- 0.0020	0.0205	+/- 0.0019	0.0126	+/- 0.0015	0.0198	+/- 0.0017	
Cl	0.0081	+/- 0.0015	0.0205	+/- 0.0020	0.0018	+/- 0.0028	0.0186	+/- 0.0018	
K	-0.0010	+/- 0.0036	-0.0005	+/- 0.0006	-0.0010	+/- 0.0034	-0.0006	+/- 0.0006	
Ca	0.0157	+/- 0.0019	0.0061	+/- 0.0006	0.0079	+/- 0.0014	0.0067	+/- 0.0006	
Tl	0.0012	+/- 0.0110	0.0000	+/- 0.0033	0.0008	+/- 0.0113	0.0001	+/- 0.0030	
V	0.0006	+/- 0.0045	0.0000	+/- 0.0013	0.0004	+/- 0.0046	0.0001	+/- 0.0012	
Cr	0.0006	+/- 0.0011	0.0004	+/- 0.0003	0.0000	+/- 0.0011	0.0003	+/- 0.0003	
Mn	0.0006	+/- 0.0009	0.0002	+/- 0.0002	0.0000	+/- 0.0009	0.0002	+/- 0.0002	
Fe	0.0294	+/- 0.0027	0.0209	+/- 0.0019	0.0167	+/- 0.0016	0.0211	+/- 0.0017	
Co	0.0002	+/- 0.0008	0.0000	+/- 0.0004	0.0000	+/- 0.0007	0.0000	+/- 0.0003	
Ni	0.0012	+/- 0.0003	0.0003	+/- 0.0001	0.0002	+/- 0.0006	0.0003	+/- 0.0001	
Cu	0.0032	+/- 0.0004	0.0046	+/- 0.0004	0.0039	+/- 0.0005	0.0045	+/- 0.0004	
Zn	0.0204	+/- 0.0019	0.0101	+/- 0.0009	0.0068	+/- 0.0007	0.0104	+/- 0.0008	
Ga	0.0001	+/- 0.0009	0.0000	+/- 0.0003	0.0002	+/- 0.0009	0.0000	+/- 0.0002	
As	0.0003	+/- 0.0040	0.0000	+/- 0.0004	0.0000	+/- 0.0011	0.0000	+/- 0.0004	
Se	0.0000	+/- 0.0005	0.0000	+/- 0.0002	0.0000	+/- 0.0005	0.0000	+/- 0.0001	
Br	0.0009	+/- 0.0002	0.0007	+/- 0.0001	0.0000	+/- 0.0006	0.0006	+/- 0.0001	
Rb	0.0001	+/- 0.0004	0.0000	+/- 0.0001	0.0001	+/- 0.0005	0.0000	+/- 0.0001	
Sr	0.0002	+/- 0.0005	0.0001	+/- 0.0001	0.0001	+/- 0.0005	0.0001	+/- 0.0001	
Y	0.0000	+/- 0.0007	0.0000	+/- 0.0002	0.0000	+/- 0.0006	0.0000	+/- 0.0002	
Zr	0.0007	+/- 0.0007	0.0001	+/- 0.0002	0.0007	+/- 0.0007	0.0002	+/- 0.0002	
Mo	0.0006	+/- 0.0013	0.0007	+/- 0.0004	0.0007	+/- 0.0014	0.0007	+/- 0.0003	
Pd	0.0000	+/- 0.0038	0.0000	+/- 0.0011	0.0000	+/- 0.0040	0.0000	+/- 0.0010	
Ag	-0.0002	+/- 0.0044	-0.0002	+/- 0.0013	-0.0002	+/- 0.0047	-0.0002	+/- 0.0012	
Cd	0.0025	+/- 0.0046	-0.0005	+/- 0.0013	0.0026	+/- 0.0049	-0.0001	+/- 0.0012	
In	-0.0001	+/- 0.0055	0.0003	+/- 0.0016	0.0044	+/- 0.0055	0.0006	+/- 0.0015	
Sn	0.0000	+/- 0.0071	0.0010	+/- 0.0020	0.0069	+/- 0.0073	0.0014	+/- 0.0019	
Sb	0.0001	+/- 0.0082	0.0016	+/- 0.0021	0.0012	+/- 0.0086	0.0015	+/- 0.0020	
Ba	0.0000	+/- 0.0308	0.0053	+/- 0.0077	0.0000	+/- 0.0314	0.0046	+/- 0.0073	
La	0.0106	+/- 0.0403	0.0000	+/- 0.0118	0.0035	+/- 0.0414	0.0008	+/- 0.0110	
Au	0.0000	+/- 0.0017	0.0000	+/- 0.0006	0.0000	+/- 0.0016	0.0000	+/- 0.0005	
Hg	-0.0001	+/- 0.0011	0.0000	+/- 0.0004	0.0005	+/- 0.0012	0.0000	+/- 0.0003	
Ti	0.0000	+/- 0.0013	0.0000	+/- 0.0003	0.0000	+/- 0.0011	0.0000	+/- 0.0003	
Pb	0.0231	+/- 0.0022	0.0008	+/- 0.0004	0.0004	+/- 0.0016	0.0020	+/- 0.0004	
U	0.0000	+/- 0.0011	0.0000	+/- 0.0003	0.0000	+/- 0.0011	0.0000	+/- 0.0003	
Total	3.2683	+/- 0.3614	2.4285	+/- 0.1657	1.3669	+/- 0.3154	2.3989	+/- 0.1485	
% Carbon	90.44%		62.25%		95.04%		64.73%		
% Inorganic	12.66%		14.60%		12.59%		14.44%		

Table E-1. Chemical Mass Emissions Rates for Ford Tempo (mg/mi)

Cycle	Unified Cycle											
	Pre-1992 California average gasoline											
Fuel	H9611050, H9612007, H9612011											
	Bag 1			Bag 2			Bag 3			Weighted		
Mass Em. Rate (mg/mi)	5.83			2.20			1.26			2.33		
Cl ⁻	-0.0002	+/-	0.0463	0.0072	+/-	0.0074	0.0190	+/-	0.0472	0.0076	+/-	0.0077
NO ₃ ⁻	-0.0280	+/-	0.0221	-0.0181	+/-	0.0071	-0.0280	+/-	0.0222	-0.0193	+/-	0.0065
(SO ₄) ²⁻	0.0205	+/-	0.0222	0.0924	+/-	0.0124	0.0310	+/-	0.0226	0.0844	+/-	0.0110
NH ₄ ⁺	0.0587	+/-	0.0493	0.0694	+/-	0.0173	0.0962	+/-	0.0581	0.0707	+/-	0.0159
OC	0.8097	+/-	0.2550	0.3436	+/-	0.0820	0.4770	+/-	0.2458	0.3770	+/-	0.0752
EC	1.9743	+/-	0.2043	1.2501	+/-	0.1264	1.2378	+/-	0.1345	1.2869	+/-	0.1120
Na	-0.0072	+/-	0.0202	-0.0072	+/-	0.0064	0.0246	+/-	0.0048	-0.0050	+/-	0.0058
Mg	0.0163	+/-	0.0036	0.0025	+/-	0.0020	0.0000	+/-	0.0078	0.0030	+/-	0.0019
Al	0.0013	+/-	0.0052	0.0002	+/-	0.0022	0.0010	+/-	0.0045	0.0003	+/-	0.0020
Si	0.0553	+/-	0.0053	0.2065	+/-	0.0185	0.0361	+/-	0.0036	0.1869	+/-	0.0163
P	0.0125	+/-	0.0015	0.0058	+/-	0.0008	0.0037	+/-	0.0009	0.0060	+/-	0.0007
S	0.0129	+/-	0.0014	0.0316	+/-	0.0029	0.0098	+/-	0.0012	0.0291	+/-	0.0025
Cl	0.0047	+/-	0.0012	0.0099	+/-	0.0011	0.0051	+/-	0.0012	0.0093	+/-	0.0010
K	-0.0004	+/-	0.0027	-0.0009	+/-	0.0005	-0.0005	+/-	0.0019	-0.0009	+/-	0.0005
Ca	0.0107	+/-	0.0014	0.0053	+/-	0.0006	0.0038	+/-	0.0010	0.0055	+/-	0.0005
Tl	0.0000	+/-	0.0090	0.0000	+/-	0.0031	0.0015	+/-	0.0088	0.0001	+/-	0.0028
V	0.0000	+/-	0.0037	0.0000	+/-	0.0013	0.0007	+/-	0.0036	0.0000	+/-	0.0012
Cr	0.0011	+/-	0.0004	0.0002	+/-	0.0003	0.0007	+/-	0.0009	0.0003	+/-	0.0002
Mn	0.0004	+/-	0.0007	0.0001	+/-	0.0002	0.0000	+/-	0.0007	0.0001	+/-	0.0002
Fe	0.0163	+/-	0.0015	0.0162	+/-	0.0015	0.0117	+/-	0.0011	0.0159	+/-	0.0013
Co	0.0002	+/-	0.0006	0.0001	+/-	0.0003	0.0000	+/-	0.0005	0.0001	+/-	0.0003
Ni	0.0010	+/-	0.0002	0.0003	+/-	0.0001	0.0001	+/-	0.0005	0.0003	+/-	0.0001
Cu	0.0040	+/-	0.0004	0.0049	+/-	0.0005	0.0034	+/-	0.0004	0.0047	+/-	0.0004
Zn	0.0120	+/-	0.0011	0.0091	+/-	0.0008	0.0048	+/-	0.0005	0.0090	+/-	0.0007
Ga	0.0004	+/-	0.0007	0.0000	+/-	0.0002	0.0003	+/-	0.0007	0.0001	+/-	0.0002
As	0.0001	+/-	0.0009	0.0000	+/-	0.0003	0.0000	+/-	0.0008	0.0000	+/-	0.0003
Se	0.0002	+/-	0.0004	0.0000	+/-	0.0001	0.0001	+/-	0.0004	0.0000	+/-	0.0001
Br	0.0001	+/-	0.0005	0.0008	+/-	0.0001	0.0000	+/-	0.0004	0.0007	+/-	0.0001
Rb	0.0000	+/-	0.0003	0.0000	+/-	0.0001	0.0001	+/-	0.0003	0.0000	+/-	0.0001
Sr	0.0002	+/-	0.0004	0.0001	+/-	0.0001	0.0002	+/-	0.0004	0.0001	+/-	0.0001
Y	0.0001	+/-	0.0005	0.0000	+/-	0.0002	0.0000	+/-	0.0005	0.0000	+/-	0.0002
Zr	0.0005	+/-	0.0005	0.0001	+/-	0.0002	0.0005	+/-	0.0005	0.0001	+/-	0.0002
Mo	0.0005	+/-	0.0010	0.0008	+/-	0.0004	0.0008	+/-	0.0010	0.0008	+/-	0.0003
Pd	0.0000	+/-	0.0031	0.0000	+/-	0.0011	0.0000	+/-	0.0031	0.0000	+/-	0.0010
Ag	-0.0002	+/-	0.0037	-0.0002	+/-	0.0012	-0.0002	+/-	0.0035	-0.0002	+/-	0.0011
Cd	0.0015	+/-	0.0037	0.0000	+/-	0.0012	0.0005	+/-	0.0036	0.0001	+/-	0.0011
In	0.0015	+/-	0.0043	0.0003	+/-	0.0015	0.0010	+/-	0.0044	0.0004	+/-	0.0013
Sn	0.0000	+/-	0.0056	0.0010	+/-	0.0017	0.0022	+/-	0.0055	0.0011	+/-	0.0016
Sb	0.0022	+/-	0.0065	0.0016	+/-	0.0021	0.0025	+/-	0.0065	0.0017	+/-	0.0019
Ba	0.0094	+/-	0.0249	0.0064	+/-	0.0077	0.0000	+/-	0.0246	0.0061	+/-	0.0071
La	0.0042	+/-	0.0324	0.0000	+/-	0.0112	0.0000	+/-	0.0323	0.0002	+/-	0.0102
Au	0.0001	+/-	0.0013	0.0000	+/-	0.0005	0.0002	+/-	0.0012	0.0000	+/-	0.0005
Hg	0.0002	+/-	0.0009	0.0000	+/-	0.0003	0.0003	+/-	0.0009	0.0000	+/-	0.0003
Ti	0.0002	+/-	0.0009	0.0000	+/-	0.0003	0.0001	+/-	0.0009	0.0000	+/-	0.0003
Pb	0.0012	+/-	0.0006	0.0004	+/-	0.0004	0.0008	+/-	0.0012	0.0004	+/-	0.0004
U	0.0001	+/-	0.0008	0.0000	+/-	0.0003	0.0000	+/-	0.0008	0.0000	+/-	0.0003
Total	2.9917	+/-	0.3355	2.0023	+/-	0.1543	1.9198	+/-	0.2914	2.0481	+/-	0.1382
% Carbon	47.75%			72.44%			136.10%			71.41%		
% Inorganic	3.56%			18.57%			16.26%			16.49%		

Table E-2. Chemical Mass Emissions Rates for Datsun 310 (mg/mi)

Cycle	FTP							
Fuel	California Phase 2							
Test #	H9612038							
Bag	Bag 1		Bag 2		Bag 3		Weighted	
Mass Em. Rate (mg/mi)	8.44		2.97		1.42		3.68	
Cl	0.0525	+/- 0.0521	0.0138	+/- 0.0446	0.0303	+/- 0.0458	0.0263	+/- 0.0284
NO ₃ ⁻	-0.0280	+/- 0.0218	-0.0280	+/- 0.0204	-0.0280	+/- 0.0215	-0.0280	+/- 0.0129
(SO ₄) ²⁻	0.0148	+/- 0.0219	0.0625	+/- 0.0217	0.0166	+/- 0.0215	0.0401	+/- 0.0135
NH ₄ ⁺	0.0498	+/- 0.0528	0.0675	+/- 0.0476	0.0316	+/- 0.0473	0.0540	+/- 0.0300
OC	1.9127	+/- 0.3103	1.4069	+/- 0.2647	3.7857	+/- 0.4523	2.1629	+/- 0.1960
EC	6.6960	+/- 0.6709	0.8598	+/- 0.1007	1.8834	+/- 0.1957	2.3425	+/- 0.1572
Na	0.0062	+/- 0.0328	0.0092	+/- 0.0242	0.0132	+/- 0.0238	0.0097	+/- 0.0157
Mg	0.0212	+/- 0.0057	0.0024	+/- 0.0120	0.0008	+/- 0.0117	0.0058	+/- 0.0071
Al	0.0073	+/- 0.0085	0.0046	+/- 0.0080	0.0037	+/- 0.0066	0.0049	+/- 0.0049
Si	0.2057	+/- 0.0188	0.3808	+/- 0.0344	0.1109	+/- 0.0103	0.2708	+/- 0.0185
P	0.0250	+/- 0.0028	0.0052	+/- 0.0013	0.0123	+/- 0.0017	0.0112	+/- 0.0010
S	0.0269	+/- 0.0034	0.0777	+/- 0.0071	0.0276	+/- 0.0029	0.0535	+/- 0.0039
Cl	0.0077	+/- 0.0016	-0.0006	+/- 0.0029	0.0004	+/- 0.0030	0.0014	+/- 0.0018
K	0.0002	+/- 0.0041	-0.0010	+/- 0.0031	-0.0010	+/- 0.0033	-0.0008	+/- 0.0020
Ca	0.0318	+/- 0.0033	0.0117	+/- 0.0015	0.0155	+/- 0.0019	0.0169	+/- 0.0012
Tl	0.0000	+/- 0.0151	0.0000	+/- 0.0112	0.0003	+/- 0.0111	0.0001	+/- 0.0073
V	0.0000	+/- 0.0093	0.0000	+/- 0.0068	0.0005	+/- 0.0045	0.0001	+/- 0.0042
Cr	0.0000	+/- 0.0030	0.0001	+/- 0.0022	0.0001	+/- 0.0011	0.0001	+/- 0.0013
Mn	0.0017	+/- 0.0005	0.0000	+/- 0.0010	0.0008	+/- 0.0009	0.0006	+/- 0.0006
Fe	0.0529	+/- 0.0048	0.0208	+/- 0.0019	0.0235	+/- 0.0022	0.0282	+/- 0.0015
Co	0.0000	+/- 0.0012	0.0002	+/- 0.0007	0.0000	+/- 0.0007	0.0001	+/- 0.0005
Ni	0.0001	+/- 0.0007	0.0001	+/- 0.0005	0.0003	+/- 0.0006	0.0001	+/- 0.0004
Cu	0.0006	+/- 0.0008	0.0002	+/- 0.0006	0.0009	+/- 0.0003	0.0005	+/- 0.0003
Zn	0.0171	+/- 0.0016	0.0034	+/- 0.0004	0.0082	+/- 0.0008	0.0075	+/- 0.0004
Ga	0.0000	+/- 0.0013	0.0005	+/- 0.0008	0.0006	+/- 0.0009	0.0004	+/- 0.0006
As	0.0000	+/- 0.0069	0.0002	+/- 0.0015	0.0004	+/- 0.0035	0.0002	+/- 0.0019
Se	0.0000	+/- 0.0008	0.0000	+/- 0.0005	0.0000	+/- 0.0005	0.0000	+/- 0.0003
Br	0.0003	+/- 0.0009	0.0003	+/- 0.0005	0.0000	+/- 0.0006	0.0002	+/- 0.0003
Rb	0.0000	+/- 0.0006	0.0000	+/- 0.0004	0.0001	+/- 0.0004	0.0000	+/- 0.0003
Sr	0.0000	+/- 0.0007	0.0000	+/- 0.0004	0.0000	+/- 0.0005	0.0000	+/- 0.0003
Y	0.0000	+/- 0.0009	0.0000	+/- 0.0006	0.0000	+/- 0.0006	0.0000	+/- 0.0004
Zr	0.0010	+/- 0.0010	0.0006	+/- 0.0007	0.0006	+/- 0.0007	0.0007	+/- 0.0004
Mo	0.0269	+/- 0.0025	0.0089	+/- 0.0010	0.0149	+/- 0.0015	0.0142	+/- 0.0008
Pd	0.0000	+/- 0.0048	0.0009	+/- 0.0037	0.0000	+/- 0.0038	0.0004	+/- 0.0024
Ag	-0.0002	+/- 0.0058	-0.0002	+/- 0.0042	-0.0002	+/- 0.0045	-0.0002	+/- 0.0028
Cd	0.0004	+/- 0.0059	0.0003	+/- 0.0045	0.0015	+/- 0.0046	0.0007	+/- 0.0029
In	0.0033	+/- 0.0068	0.0023	+/- 0.0052	0.0048	+/- 0.0054	0.0032	+/- 0.0034
Sn	0.0035	+/- 0.0086	0.0008	+/- 0.0065	0.0023	+/- 0.0069	0.0017	+/- 0.0042
Sb	0.0014	+/- 0.0105	0.0000	+/- 0.0078	0.0000	+/- 0.0081	0.0003	+/- 0.0051
Ba	0.0000	+/- 0.0383	0.0000	+/- 0.0286	0.0000	+/- 0.0310	0.0000	+/- 0.0188
La	0.0240	+/- 0.0518	0.0148	+/- 0.0382	0.0000	+/- 0.0411	0.0126	+/- 0.0252
Au	0.0000	+/- 0.0021	0.0001	+/- 0.0014	0.0006	+/- 0.0015	0.0002	+/- 0.0010
Hg	0.0001	+/- 0.0016	0.0000	+/- 0.0011	0.0004	+/- 0.0012	0.0001	+/- 0.0007
Ti	0.0000	+/- 0.0020	0.0000	+/- 0.0011	0.0000	+/- 0.0013	0.0000	+/- 0.0008
Pb	0.0418	+/- 0.0039	0.0063	+/- 0.0009	0.0201	+/- 0.0020	0.0174	+/- 0.0011
U	0.0000	+/- 0.0015	0.0000	+/- 0.0010	0.0000	+/- 0.0011	0.0000	+/- 0.0007
Total	9.1470	+/- 0.7461	2.8983	+/- 0.2967	5.9476	+/- 0.4999	5.0211	+/- 0.2573
% Carbon	102.00%		76.32%		399.23%		122.43%	
% Inorganic	6.38%		21.27%		19.62%		14.01%	

Table E-2. Chemical Mass Emissions Rates for Datsun 310 (mg/mi)

Cycle	FTP					
Fuel	Pre-1992 California Average					
Test #	H9612046					
Bag	Bag 1		Bag 2		Bag 3	
Mass Em. Rate (mg/mi)	23.15		0.77		1.62	
Cl ⁻	0.0631	+/- 0.0548	0.0935	+/- 0.0463	0.0363	+/- 0.0487
NO ₃ ⁻	-0.0280	+/- 0.0238	-0.0280	+/- 0.0199	-0.0280	+/- 0.0218
(SO ₄) ²⁻	0.2435	+/- 0.0362	0.0116	+/- 0.0199	0.0696	+/- 0.0233
NH ₄ ⁺	0.1764	+/- 0.0598	0.0445	+/- 0.0442	0.0839	+/- 0.0513
OC	2.1933	+/- 0.3440	0.4886	+/- 0.2208	0.2025	+/- 0.2336
EC	14.6422	+/- 1.4634	0.5360	+/- 0.0729	0.5184	+/- 0.0726
Na	-0.0072	+/- 0.0392	-0.0056	+/- 0.0185	-0.0040	+/- 0.0237
Mg	0.0083	+/- 0.0276	0.0066	+/- 0.0085	0.0048	+/- 0.0100
Al	0.0040	+/- 0.0166	0.0017	+/- 0.0046	0.0039	+/- 0.0059
Si	0.3488	+/- 0.0322	0.0980	+/- 0.0091	0.0946	+/- 0.0088
P	0.0157	+/- 0.0036	0.0032	+/- 0.0009	0.0035	+/- 0.0012
S	0.2190	+/- 0.0203	0.0052	+/- 0.0009	0.0474	+/- 0.0045
Cl	0.0188	+/- 0.0037	0.0014	+/- 0.0023	0.0023	+/- 0.0011
K	-0.0010	+/- 0.0063	-0.0002	+/- 0.0019	0.0007	+/- 0.0021
Ca	0.0273	+/- 0.0034	0.0088	+/- 0.0013	0.0151	+/- 0.0018
Tl	0.0005	+/- 0.0198	0.0000	+/- 0.0103	0.0003	+/- 0.0107
V	0.0000	+/- 0.0081	0.0000	+/- 0.0061	0.0001	+/- 0.0044
Cr	0.0000	+/- 0.0019	0.0000	+/- 0.0019	0.0002	+/- 0.0011
Mn	0.0000	+/- 0.0015	0.0000	+/- 0.0009	0.0000	+/- 0.0008
Fe	0.0425	+/- 0.0040	0.0114	+/- 0.0011	0.0267	+/- 0.0025
Co	0.0003	+/- 0.0016	0.0000	+/- 0.0005	0.0000	+/- 0.0007
Ni	0.0001	+/- 0.0010	0.0001	+/- 0.0005	0.0000	+/- 0.0005
Cu	0.0012	+/- 0.0004	0.0002	+/- 0.0005	0.0001	+/- 0.0006
Zn	0.0151	+/- 0.0015	0.0014	+/- 0.0003	0.0036	+/- 0.0004
Ga	0.0000	+/- 0.0019	0.0000	+/- 0.0007	0.0000	+/- 0.0009
As	0.0000	+/- 0.0106	0.0004	+/- 0.0010	0.0000	+/- 0.0019
Se	0.0000	+/- 0.0010	0.0001	+/- 0.0004	0.0000	+/- 0.0005
Br	0.0006	+/- 0.0013	0.0000	+/- 0.0004	0.0000	+/- 0.0005
Rb	0.0000	+/- 0.0008	0.0000	+/- 0.0004	0.0000	+/- 0.0005
Sr	0.0000	+/- 0.0009	0.0001	+/- 0.0004	0.0000	+/- 0.0005
Y	0.0000	+/- 0.0013	0.0000	+/- 0.0005	0.0000	+/- 0.0007
Zr	0.0008	+/- 0.0014	0.0006	+/- 0.0006	0.0007	+/- 0.0008
Mo	0.0290	+/- 0.0028	0.0047	+/- 0.0007	0.0086	+/- 0.0010
Pd	0.0000	+/- 0.0071	0.0000	+/- 0.0034	0.0000	+/- 0.0038
Ag	-0.0002	+/- 0.0082	0.0005	+/- 0.0040	-0.0002	+/- 0.0044
Cd	-0.0005	+/- 0.0082	0.0025	+/- 0.0040	0.0015	+/- 0.0046
In	0.0052	+/- 0.0101	-0.0001	+/- 0.0046	-0.0001	+/- 0.0052
Sn	0.0048	+/- 0.0128	0.0007	+/- 0.0061	0.0016	+/- 0.0068
Sb	0.0023	+/- 0.0148	0.0000	+/- 0.0069	0.0000	+/- 0.0082
Ba	0.0000	+/- 0.0545	0.0187	+/- 0.0258	0.0000	+/- 0.0299
La	0.0005	+/- 0.0738	0.0154	+/- 0.0340	0.0000	+/- 0.0397
Au	0.0000	+/- 0.0030	0.0000	+/- 0.0013	0.0000	+/- 0.0015
Hg	0.0006	+/- 0.0023	-0.0001	+/- 0.0010	-0.0001	+/- 0.0012
Ti	0.0000	+/- 0.0029	0.0000	+/- 0.0010	0.0001	+/- 0.0012
Pb	0.0414	+/- 0.0041	0.0023	+/- 0.0006	0.0083	+/- 0.0010
U	0.0000	+/- 0.0021	0.0000	+/- 0.0009	0.0000	+/- 0.0012
Total	17.9241	+/- 1.5096	1.2268	+/- 0.2438	1.0431	+/- 0.2590
% Carbon	72.72%		133.07%		44.50%	74.84%
% Inorganic	4.70%		26.26%		19.89%	7.45%

Table E-2. Chemical Mass Emissions Rates for Datsun 310 (mg/mi)

Cycle	Unified Cycle							
Fuel	California Phase 2							
Test #	H9612042							
Bag	Bag 1		Bag 2		Bag 3		Weighted	
Mass Em. Rate (mg/mi)	56.81		17.55		2.40		18.56	
Cl ⁻	0.0689	+/- 0.1401	0.0549	+/- 0.0056	0.1636	+/- 0.1630	0.0632	+/- 0.0143
NO ₃ ⁻	-0.0280	+/- 0.0634	0.0132	+/- 0.0063	-0.0280	+/- 0.0720	0.0082	+/- 0.0081
(SO ₄) ²⁻	0.0150	+/- 0.0637	1.5957	+/- 0.1428	0.0212	+/- 0.0724	1.4048	+/- 0.1257
NH ₄ ⁺	-0.0036	+/- 0.1392	0.7487	+/- 0.0682	0.0571	+/- 0.1590	0.6618	+/- 0.0614
OC	12.3559	+/- 1.4398	3.8434	+/- 0.3497	-0.1800	+/- 0.7774	4.0084	+/- 0.3209
EC	38.0291	+/- 3.8016	1.8454	+/- 0.1656	1.1842	+/- 0.2154	3.6814	+/- 0.2460
Na	0.0645	+/- 0.0904	0.0242	+/- 0.0025	-0.0072	+/- 0.0774	0.0241	+/- 0.0075
Mg	0.0570	+/- 0.0143	0.0071	+/- 0.0018	-0.0012	+/- 0.0337	0.0091	+/- 0.0029
Al	0.0362	+/- 0.0083	-0.0003	+/- 0.0011	0.0221	+/- 0.0071	0.0031	+/- 0.0012
Si	0.7647	+/- 0.0695	1.8532	+/- 0.1658	0.0435	+/- 0.0061	1.6717	+/- 0.1457
P	0.0423	+/- 0.0059	0.0083	+/- 0.0009	0.0291	+/- 0.0041	0.0115	+/- 0.0009
S	0.0937	+/- 0.0103	1.1447	+/- 0.1024	0.0208	+/- 0.0041	1.0125	+/- 0.0900
Cl	0.0397	+/- 0.0055	0.0041	+/- 0.0007	-0.0006	+/- 0.0088	0.0056	+/- 0.0009
K	0.0040	+/- 0.0077	-0.0003	+/- 0.0002	-0.0010	+/- 0.0124	-0.0001	+/- 0.0010
Ca	0.0599	+/- 0.0068	0.0290	+/- 0.0026	0.0276	+/- 0.0048	0.0305	+/- 0.0023
Tl	0.0000	+/- 0.0379	0.0006	+/- 0.0027	0.0000	+/- 0.0418	0.0005	+/- 0.0042
V	0.0000	+/- 0.0154	0.0001	+/- 0.0011	0.0013	+/- 0.0170	0.0002	+/- 0.0017
Cr	0.0000	+/- 0.0038	0.0012	+/- 0.0003	0.0022	+/- 0.0040	0.0012	+/- 0.0004
Mn	0.0003	+/- 0.0030	0.0017	+/- 0.0003	0.0004	+/- 0.0030	0.0016	+/- 0.0003
Fe	0.1241	+/- 0.0113	0.0945	+/- 0.0085	0.1063	+/- 0.0098	0.0969	+/- 0.0075
Co	0.0001	+/- 0.0030	0.0000	+/- 0.0001	0.0000	+/- 0.0028	0.0000	+/- 0.0003
Ni	-0.0001	+/- 0.0020	0.0006	+/- 0.0002	0.0001	+/- 0.0020	0.0006	+/- 0.0002
Cu	0.0008	+/- 0.0021	0.0016	+/- 0.0002	0.0017	+/- 0.0021	0.0016	+/- 0.0003
Zn	0.0314	+/- 0.0030	0.0191	+/- 0.0017	0.0168	+/- 0.0018	0.0196	+/- 0.0015
Ga	0.0000	+/- 0.0034	0.0000	+/- 0.0002	0.0000	+/- 0.0034	0.0000	+/- 0.0004
As	0.0000	+/- 0.0151	0.0005	+/- 0.0003	0.0000	+/- 0.0078	0.0005	+/- 0.0010
Se	0.0000	+/- 0.0019	0.0000	+/- 0.0001	0.0000	+/- 0.0020	0.0000	+/- 0.0002
Br	0.0006	+/- 0.0023	0.0024	+/- 0.0002	0.0000	+/- 0.0019	0.0021	+/- 0.0003
Rb	0.0001	+/- 0.0016	0.0000	+/- 0.0001	0.0003	+/- 0.0017	0.0000	+/- 0.0002
Sr	0.0000	+/- 0.0018	0.0000	+/- 0.0001	0.0000	+/- 0.0019	0.0000	+/- 0.0002
Y	0.0000	+/- 0.0024	0.0001	+/- 0.0002	0.0000	+/- 0.0024	0.0001	+/- 0.0003
Zr	0.0026	+/- 0.0026	0.0004	+/- 0.0002	0.0027	+/- 0.0028	0.0007	+/- 0.0003
Mo	0.0546	+/- 0.0052	0.0311	+/- 0.0028	0.0254	+/- 0.0029	0.0319	+/- 0.0025
Pd	0.0000	+/- 0.0133	0.0000	+/- 0.0009	0.0000	+/- 0.0145	0.0000	+/- 0.0015
Ag	-0.0002	+/- 0.0155	-0.0002	+/- 0.0011	-0.0002	+/- 0.0159	-0.0002	+/- 0.0017
Cd	0.0014	+/- 0.0163	-0.0002	+/- 0.0011	0.0119	+/- 0.0176	0.0007	+/- 0.0018
In	-0.0001	+/- 0.0184	-0.0001	+/- 0.0013	0.0068	+/- 0.0202	0.0004	+/- 0.0021
Sn	0.0189	+/- 0.0243	0.0004	+/- 0.0017	0.0046	+/- 0.0261	0.0016	+/- 0.0027
Sb	0.0000	+/- 0.0284	0.0000	+/- 0.0020	0.0005	+/- 0.0313	0.0000	+/- 0.0032
Ba	0.0000	+/- 0.1054	0.0003	+/- 0.0075	0.0000	+/- 0.1155	0.0003	+/- 0.0117
La	0.0195	+/- 0.1406	0.0000	+/- 0.0101	0.0000	+/- 0.1523	0.0010	+/- 0.0156
Au	0.0000	+/- 0.0055	0.0000	+/- 0.0004	0.0000	+/- 0.0059	0.0000	+/- 0.0006
Hg	0.0019	+/- 0.0043	0.0001	+/- 0.0003	-0.0001	+/- 0.0045	0.0002	+/- 0.0005
Ti	0.0000	+/- 0.0050	0.0000	+/- 0.0003	0.0008	+/- 0.0046	0.0001	+/- 0.0005
Pb	0.0889	+/- 0.0084	0.0379	+/- 0.0034	0.0377	+/- 0.0042	0.0405	+/- 0.0030
U	0.0000	+/- 0.0040	0.0000	+/- 0.0003	0.0000	+/- 0.0043	0.0000	+/- 0.0004
Total	51.8702	+/- 4.0745	10.7768	+/- 0.4501	1.3998	+/- 0.8577	12.2667	+/- 0.4527
% Carbon	88.69%		32.42%		41.84%		41.43%	
% Inorganic	2.61%		28.99%		16.48%		24.66%	

Table E-2. Chemical Mass Emissions Rates for Datsun 310 (mg/mi)

Cycle	Unified Cycle							
	Pre-1992 California average gasoline							
Test #	H9612051							
	Bag	Bag 1	Bag 2	Bag 3	Weighted			
Mass Em. Rate (mg/mi)		102.04	10.90	1.89		15.08		
Cl ⁻	0.0993	+/- 0.1598	0.0097	+/- 0.0194	0.1182	+/- 0.1683	0.0218	+/- 0.0222
NO ₃ ⁻	-0.0280	+/- 0.0656	0.0057	+/- 0.0109	-0.0280	+/- 0.0756	0.0016	+/- 0.0114
(SO ₄) ²⁻	0.0990	+/- 0.0671	0.5899	+/- 0.0652	0.0417	+/- 0.0761	0.5265	+/- 0.0577
NH ₄ ⁺	0.1823	+/- 0.1836	0.2904	+/- 0.0436	0.0284	+/- 0.1664	0.2667	+/- 0.0411
OC	7.7556	+/- 1.0730	2.0710	+/- 0.2431	0.2030	+/- 0.8161	2.2378	+/- 0.2279
EC	83.3190	+/- 8.3258	2.5879	+/- 0.2608	0.5403	+/- 0.1876	6.6447	+/- 0.4901
Na	-0.0014	+/- 0.1123	-0.0072	+/- 0.0300	0.0292	+/- 0.0627	-0.0044	+/- 0.0273
Mg	0.0390	+/- 0.0540	0.0223	+/- 0.0060	0.0073	+/- 0.0349	0.0221	+/- 0.0065
Al	-0.0003	+/- 0.0313	-0.0003	+/- 0.0099	0.0095	+/- 0.0201	0.0004	+/- 0.0089
Si	1.3684	+/- 0.1235	1.7596	+/- 0.1575	0.0481	+/- 0.0065	1.6211	+/- 0.1386
P	0.0380	+/- 0.0063	0.0131	+/- 0.0021	0.0129	+/- 0.0032	0.0144	+/- 0.0019
S	0.2391	+/- 0.0227	0.3770	+/- 0.0339	0.0140	+/- 0.0035	0.3448	+/- 0.0298
Cl	0.0464	+/- 0.0065	0.0048	+/- 0.0067	0.0030	+/- 0.0105	0.0069	+/- 0.0059
K	0.0089	+/- 0.0031	-0.0009	+/- 0.0018	0.0001	+/- 0.0092	-0.0003	+/- 0.0017
Ca	0.0707	+/- 0.0078	0.0344	+/- 0.0032	0.0189	+/- 0.0046	0.0352	+/- 0.0029
Tl	0.0000	+/- 0.0429	0.0010	+/- 0.0060	0.0014	+/- 0.0446	0.0009	+/- 0.0065
V	0.0000	+/- 0.0175	0.0005	+/- 0.0024	0.0000	+/- 0.0182	0.0005	+/- 0.0026
Cr	0.0000	+/- 0.0043	0.0008	+/- 0.0003	0.0000	+/- 0.0044	0.0007	+/- 0.0005
Mn	0.0007	+/- 0.0034	0.0014	+/- 0.0003	0.0000	+/- 0.0034	0.0013	+/- 0.0004
Fe	0.0621	+/- 0.0058	0.0670	+/- 0.0060	0.0491	+/- 0.0047	0.0655	+/- 0.0053
Co	0.0000	+/- 0.0025	0.0000	+/- 0.0011	0.0000	+/- 0.0025	0.0000	+/- 0.0010
Ni	0.0021	+/- 0.0023	0.0007	+/- 0.0002	-0.0001	+/- 0.0023	0.0007	+/- 0.0003
Cu	0.0005	+/- 0.0023	0.0013	+/- 0.0002	0.0015	+/- 0.0025	0.0013	+/- 0.0003
Zn	0.0318	+/- 0.0030	0.0239	+/- 0.0022	0.0074	+/- 0.0011	0.0231	+/- 0.0019
Ga	0.0000	+/- 0.0038	0.0000	+/- 0.0008	0.0000	+/- 0.0036	0.0000	+/- 0.0008
As	0.0000	+/- 0.0164	0.0000	+/- 0.0090	0.0000	+/- 0.0051	0.0000	+/- 0.0080
Se	0.0000	+/- 0.0022	0.0000	+/- 0.0004	0.0007	+/- 0.0021	0.0000	+/- 0.0004
Br	0.0029	+/- 0.0008	0.0012	+/- 0.0002	0.0000	+/- 0.0019	0.0012	+/- 0.0003
Rb	0.0000	+/- 0.0019	0.0000	+/- 0.0003	0.0000	+/- 0.0018	0.0000	+/- 0.0003
Sr	0.0000	+/- 0.0021	0.0000	+/- 0.0003	0.0009	+/- 0.0020	0.0001	+/- 0.0003
Y	0.0000	+/- 0.0027	0.0000	+/- 0.0006	0.0002	+/- 0.0025	0.0000	+/- 0.0006
Zr	0.0030	+/- 0.0030	0.0004	+/- 0.0004	0.0028	+/- 0.0029	0.0007	+/- 0.0004
Mo	0.0625	+/- 0.0060	0.0403	+/- 0.0036	0.0140	+/- 0.0022	0.0396	+/- 0.0032
Pd	0.0000	+/- 0.0149	0.0000	+/- 0.0022	0.0000	+/- 0.0152	0.0000	+/- 0.0023
Ag	-0.0002	+/- 0.0171	-0.0001	+/- 0.0025	0.0002	+/- 0.0180	-0.0001	+/- 0.0027
Cd	0.0031	+/- 0.0183	0.0004	+/- 0.0026	0.0070	+/- 0.0189	0.0010	+/- 0.0028
In	-0.0001	+/- 0.0205	0.0017	+/- 0.0030	0.0044	+/- 0.0225	0.0018	+/- 0.0032
Sn	0.0014	+/- 0.0263	0.0036	+/- 0.0021	0.0172	+/- 0.0286	0.0044	+/- 0.0030
Sb	0.0000	+/- 0.0321	0.0018	+/- 0.0045	0.0000	+/- 0.0330	0.0016	+/- 0.0049
Ba	0.0079	+/- 0.1198	0.0000	+/- 0.0165	0.0000	+/- 0.1239	0.0004	+/- 0.0180
La	0.0000	+/- 0.1546	0.0005	+/- 0.0220	0.0000	+/- 0.1639	0.0004	+/- 0.0238
Au	0.0000	+/- 0.0063	0.0000	+/- 0.0013	0.0000	+/- 0.0059	0.0000	+/- 0.0013
Hg	-0.0001	+/- 0.0049	-0.0001	+/- 0.0007	0.0009	+/- 0.0047	0.0000	+/- 0.0008
Ti	0.0000	+/- 0.0056	0.0001	+/- 0.0017	0.0005	+/- 0.0046	0.0002	+/- 0.0016
Pb	0.0963	+/- 0.0092	0.0567	+/- 0.0051	0.0134	+/- 0.0026	0.0558	+/- 0.0045
U	0.0000	+/- 0.0046	0.0000	+/- 0.0007	0.0000	+/- 0.0044	0.0000	+/- 0.0007
Total	93.3774	+/- 8.4018	7.7544	+/- 0.4004	1.0362	+/- 0.8912	11.7432	+/- 0.5644
% Carbon	89.25%		42.74%		39.33%		58.90%	
% Inorganic	2.26%		28.40%		15.50%		18.97%	

Table E-3. Chemical Mass Emissions Rates for Ford Mustang (mg/mi)

Cycle	FTP							
Fuel	California Phase 2							
Test #	H9612025							
Bag	Bag 1		Bag 2		Bag 3		Weighted	
Mass Em. Rate (mg/mi)	13.13		5.50		17.06		10.25	
Cl ⁻	0.1269	+/- 0.1176	0.2308	+/- 0.1236	0.0223	+/- 0.1134	0.1523	+/- 0.0754
NO ₃ ⁻	-0.0280	+/- 0.0520	-0.0280	+/- 0.0516	-0.0280	+/- 0.0519	-0.0280	+/- 0.0322
(SO ₄) ²⁻	0.0547	+/- 0.0526	0.0129	+/- 0.0518	0.0500	+/- 0.0526	0.0317	+/- 0.0324
NH ₄ ⁺	0.0487	+/- 0.1147	0.0604	+/- 0.1141	0.0431	+/- 0.1146	0.0532	+/- 0.0712
OC	9.6165	+/- 1.1364	6.8598	+/- 0.9052	13.7032	+/- 1.5099	9.3028	+/- 0.6690
EC	1.0606	+/- 0.1651	2.0218	+/- 0.2395	3.7792	+/- 0.3974	2.3053	+/- 0.1689
Na	-0.0072	+/- 0.0731	0.1225	+/- 0.0277	0.1030	+/- 0.0177	0.0904	+/- 0.0214
Mg	0.0430	+/- 0.0105	0.0272	+/- 0.0096	0.0326	+/- 0.0113	0.0319	+/- 0.0063
Al	0.0139	+/- 0.0180	0.0024	+/- 0.0160	-0.0003	+/- 0.0196	0.0040	+/- 0.0106
Si	0.0383	+/- 0.0058	0.0378	+/- 0.0057	0.0505	+/- 0.0068	0.0414	+/- 0.0037
P	0.0246	+/- 0.0037	0.0066	+/- 0.0078	0.0255	+/- 0.0038	0.0155	+/- 0.0043
S	0.0139	+/- 0.0032	0.0087	+/- 0.0025	0.0254	+/- 0.0035	0.0144	+/- 0.0018
Cl	0.0032	+/- 0.0101	-0.0006	+/- 0.0095	0.0032	+/- 0.0102	0.0012	+/- 0.0060
K	0.0038	+/- 0.0091	-0.0009	+/- 0.0086	-0.0010	+/- 0.0131	0.0001	+/- 0.0060
Ca	0.0066	+/- 0.0123	-0.0008	+/- 0.0113	0.0016	+/- 0.0120	0.0014	+/- 0.0072
Tl	0.0000	+/- 0.0488	0.0000	+/- 0.0426	0.0000	+/- 0.0475	0.0000	+/- 0.0276
V	0.0000	+/- 0.0296	0.0001	+/- 0.0173	0.0000	+/- 0.0291	0.0001	+/- 0.0135
Cr	0.0000	+/- 0.0093	0.0002	+/- 0.0041	0.0000	+/- 0.0091	0.0001	+/- 0.0038
Mn	0.0000	+/- 0.0043	0.0002	+/- 0.0032	0.0000	+/- 0.0040	0.0001	+/- 0.0022
Fe	0.0191	+/- 0.0022	0.0316	+/- 0.0032	0.0223	+/- 0.0024	0.0265	+/- 0.0018
Co	0.0000	+/- 0.0023	0.0007	+/- 0.0022	0.0006	+/- 0.0022	0.0005	+/- 0.0014
Ni	0.0001	+/- 0.0023	0.0003	+/- 0.0021	-0.0001	+/- 0.0021	0.0002	+/- 0.0013
Cu	0.0013	+/- 0.0025	0.0002	+/- 0.0022	0.0018	+/- 0.0023	0.0009	+/- 0.0014
Zn	0.0105	+/- 0.0013	0.0028	+/- 0.0008	0.0072	+/- 0.0011	0.0056	+/- 0.0006
Ga	0.0000	+/- 0.0035	0.0009	+/- 0.0032	0.0003	+/- 0.0034	0.0005	+/- 0.0020
As	0.0032	+/- 0.0042	0.0005	+/- 0.0037	0.0000	+/- 0.0040	0.0009	+/- 0.0024
Se	0.0003	+/- 0.0021	0.0000	+/- 0.0018	0.0000	+/- 0.0020	0.0001	+/- 0.0012
Br	0.0000	+/- 0.0019	0.0000	+/- 0.0017	0.0000	+/- 0.0018	0.0000	+/- 0.0011
Rb	0.0000	+/- 0.0017	0.0000	+/- 0.0015	0.0001	+/- 0.0017	0.0000	+/- 0.0010
Sr	0.0000	+/- 0.0020	0.0000	+/- 0.0017	0.0000	+/- 0.0019	0.0000	+/- 0.0011
Y	0.0007	+/- 0.0025	0.0001	+/- 0.0022	0.0000	+/- 0.0023	0.0002	+/- 0.0014
Zr	0.0029	+/- 0.0029	0.0025	+/- 0.0026	0.0028	+/- 0.0028	0.0027	+/- 0.0016
Mo	0.0007	+/- 0.0053	0.0005	+/- 0.0047	0.0003	+/- 0.0051	0.0005	+/- 0.0030
Pd	0.0000	+/- 0.0153	0.0000	+/- 0.0145	0.0000	+/- 0.0149	0.0000	+/- 0.0091
Ag	-0.0002	+/- 0.0183	-0.0002	+/- 0.0168	-0.0002	+/- 0.0178	-0.0002	+/- 0.0107
Cd	-0.0001	+/- 0.0185	-0.0005	+/- 0.0176	0.0064	+/- 0.0180	0.0015	+/- 0.0111
In	0.0048	+/- 0.0219	0.0050	+/- 0.0205	0.0172	+/- 0.0214	0.0083	+/- 0.0130
Sn	0.0067	+/- 0.0281	0.0027	+/- 0.0257	0.0000	+/- 0.0265	0.0028	+/- 0.0163
Sb	0.0000	+/- 0.0326	0.0080	+/- 0.0308	0.0000	+/- 0.0322	0.0041	+/- 0.0195
Ba	0.0000	+/- 0.1237	0.0000	+/- 0.1127	0.0675	+/- 0.1187	0.0185	+/- 0.0717
La	0.0710	+/- 0.1618	0.0000	+/- 0.1524	0.1134	+/- 0.1579	0.0457	+/- 0.0962
Au	0.0000	+/- 0.0060	0.0002	+/- 0.0054	0.0000	+/- 0.0058	0.0001	+/- 0.0034
Hg	-0.0001	+/- 0.0046	0.0011	+/- 0.0042	-0.0001	+/- 0.0044	0.0005	+/- 0.0027
Ti	0.0000	+/- 0.0044	0.0011	+/- 0.0040	0.0005	+/- 0.0043	0.0007	+/- 0.0026
Pb	0.0019	+/- 0.0061	0.0017	+/- 0.0055	0.0021	+/- 0.0059	0.0018	+/- 0.0035
U	0.0001	+/- 0.0044	0.0000	+/- 0.0039	0.0000	+/- 0.0042	0.0000	+/- 0.0025
Total	10.9972	+/- 1.1797	9.1851	+/- 0.9683	18.0134	+/- 1.5822	11.9774	+/- 0.7075
% Carbon	81.32%		161.48%		102.48%		113.25%	
% Inorganic	2.44%		5.52%		3.11%		3.60%	

Table E-3. Chemical Mass Emissions Rates for Ford Mustang (mg/mi)

Cycle	FTP							
Fuel	Pre-1992 California Average							
Test #	H9612029							
Bag	Bag 1		Bag 2		Bag 3		Weighted	
Mass Em. Rate (mg/mi)	16.34		10.49		24.93		15.66	
Cl ⁻	0.0613	+/- 0.0486	0.0297	+/- 0.0439	0.0498	+/- 0.0480	0.0417	+/- 0.0282
NO ₃ ⁻	-0.0280	+/- 0.0220	-0.0280	+/- 0.0206	-0.0280	+/- 0.0220	-0.0280	+/- 0.0131
(SO ₄) ²⁻	0.0471	+/- 0.0227	0.0241	+/- 0.0208	0.0462	+/- 0.0227	0.0349	+/- 0.0133
NH ₄ ⁺	0.0287	+/- 0.0484	0.0358	+/- 0.0456	0.0393	+/- 0.0487	0.0353	+/- 0.0290
OC	10.5979	+/- 1.1010	7.7083	+/- 0.8149	14.7131	+/- 1.5063	10.2229	+/- 0.6335
EC	2.4742	+/- 0.2539	2.5881	+/- 0.2639	4.4883	+/- 0.4509	3.0853	+/- 0.1919
Na	-0.0072	+/- 0.0172	-0.0066	+/- 0.0168	0.0101	+/- 0.0219	-0.0022	+/- 0.0112
Mg	0.0101	+/- 0.0037	0.0069	+/- 0.0084	0.0182	+/- 0.0042	0.0107	+/- 0.0046
Al	0.0048	+/- 0.0021	-0.0003	+/- 0.0049	-0.0003	+/- 0.0059	0.0008	+/- 0.0030
Si	0.0239	+/- 0.0026	0.0298	+/- 0.0031	0.0324	+/- 0.0035	0.0293	+/- 0.0019
P	0.0227	+/- 0.0024	0.0063	+/- 0.0011	0.0213	+/- 0.0023	0.0138	+/- 0.0010
S	0.0271	+/- 0.0026	0.0123	+/- 0.0014	0.0338	+/- 0.0032	0.0212	+/- 0.0013
Cl	0.0064	+/- 0.0013	0.0015	+/- 0.0023	0.0051	+/- 0.0012	0.0035	+/- 0.0013
K	-0.0010	+/- 0.0028	-0.0006	+/- 0.0018	0.0005	+/- 0.0033	-0.0004	+/- 0.0014
Ca	0.0030	+/- 0.0009	0.0015	+/- 0.0025	0.0014	+/- 0.0030	0.0018	+/- 0.0016
Tl	0.0000	+/- 0.0092	0.0000	+/- 0.0102	0.0000	+/- 0.0110	0.0000	+/- 0.0064
V	0.0001	+/- 0.0037	0.0000	+/- 0.0061	0.0000	+/- 0.0045	0.0000	+/- 0.0035
Cr	0.0006	+/- 0.0009	0.0000	+/- 0.0019	0.0000	+/- 0.0011	0.0001	+/- 0.0011
Mn	0.0003	+/- 0.0007	0.0000	+/- 0.0009	0.0000	+/- 0.0008	0.0001	+/- 0.0005
Fe	0.0138	+/- 0.0013	0.0263	+/- 0.0024	0.0175	+/- 0.0016	0.0213	+/- 0.0014
Co	0.0002	+/- 0.0006	0.0000	+/- 0.0007	0.0000	+/- 0.0006	0.0000	+/- 0.0004
Ni	0.0007	+/- 0.0002	-0.0001	+/- 0.0005	0.0000	+/- 0.0006	0.0001	+/- 0.0003
Cu	0.0021	+/- 0.0003	0.0004	+/- 0.0005	0.0012	+/- 0.0003	0.0009	+/- 0.0003
Zn	0.0098	+/- 0.0009	0.0021	+/- 0.0003	0.0060	+/- 0.0006	0.0048	+/- 0.0003
Ga	0.0002	+/- 0.0007	0.0002	+/- 0.0008	0.0000	+/- 0.0009	0.0001	+/- 0.0005
As	0.0000	+/- 0.0010	0.0002	+/- 0.0009	0.0000	+/- 0.0011	0.0001	+/- 0.0006
Se	0.0001	+/- 0.0004	0.0000	+/- 0.0004	0.0000	+/- 0.0006	0.0000	+/- 0.0003
Br	0.0000	+/- 0.0005	0.0000	+/- 0.0005	0.0002	+/- 0.0005	0.0001	+/- 0.0003
Rb	0.0000	+/- 0.0004	0.0000	+/- 0.0004	0.0002	+/- 0.0005	0.0001	+/- 0.0002
Sr	0.0001	+/- 0.0004	0.0000	+/- 0.0004	0.0000	+/- 0.0005	0.0000	+/- 0.0003
Y	0.0000	+/- 0.0005	0.0000	+/- 0.0005	0.0000	+/- 0.0007	0.0000	+/- 0.0003
Zr	0.0005	+/- 0.0006	0.0006	+/- 0.0006	0.0007	+/- 0.0008	0.0006	+/- 0.0004
Mo	0.0000	+/- 0.0010	0.0000	+/- 0.0011	0.0000	+/- 0.0014	0.0000	+/- 0.0007
Pd	0.0000	+/- 0.0032	0.0003	+/- 0.0034	0.0000	+/- 0.0039	0.0002	+/- 0.0022
Ag	-0.0002	+/- 0.0038	-0.0002	+/- 0.0037	-0.0002	+/- 0.0044	-0.0002	+/- 0.0024
Cd	0.0012	+/- 0.0038	0.0011	+/- 0.0039	0.0013	+/- 0.0045	0.0012	+/- 0.0025
In	0.0037	+/- 0.0045	0.0007	+/- 0.0046	0.0026	+/- 0.0055	0.0019	+/- 0.0030
Sn	0.0063	+/- 0.0026	0.0032	+/- 0.0059	0.0047	+/- 0.0070	0.0042	+/- 0.0036
Sb	0.0001	+/- 0.0068	0.0008	+/- 0.0070	0.0053	+/- 0.0082	0.0019	+/- 0.0045
Ba	0.0000	+/- 0.0256	0.0072	+/- 0.0260	0.0102	+/- 0.0305	0.0066	+/- 0.0168
La	0.0016	+/- 0.0341	0.0206	+/- 0.0343	0.0000	+/- 0.0404	0.0110	+/- 0.0221
Au	0.0000	+/- 0.0013	0.0000	+/- 0.0012	0.0000	+/- 0.0016	0.0000	+/- 0.0008
Hg	0.0007	+/- 0.0010	0.0004	+/- 0.0010	-0.0001	+/- 0.0012	0.0003	+/- 0.0007
Ti	0.0000	+/- 0.0009	0.0000	+/- 0.0009	0.0001	+/- 0.0012	0.0000	+/- 0.0006
Pb	0.0028	+/- 0.0006	-0.0001	+/- 0.0013	-0.0001	+/- 0.0016	0.0005	+/- 0.0008
U	0.0001	+/- 0.0009	0.0000	+/- 0.0010	0.0000	+/- 0.0012	0.0000	+/- 0.0006
Total	13.2388	+/- 1.1324	10.4347	+/- 0.8598	19.4156	+/- 1.5745	13.4731	+/- 0.6637
% Carbon	80.00%		98.15%		77.02%		84.98%	
% Inorganic	1.02%		1.32%		0.86%		1.05%	

**Appendix F. Statistical Summary of the Chemical Composition Differences for Different
Phase 1 Test Vehicles**

Table F-1. Statistical Summary of Relative Organic and Elemental Carbon Fractions for Different Vehicles (% of Total Particulate Carbon)

	Ford Tempo	Datsun 310	Ford Mustang	P-Value	Pairwise Differences
Organic Carbon	28.3%	35.9%	76.2%	<u>0.0005</u>	2,3
Elemental Carbon	71.7%	64.1%	23.8%		

Underlined P-values indicated that there are statistically significant differences between one or more vehicles for organic and elemental carbon fractions at the 95% confidence level.

Pairwise differences indicate which vehicle pairs are statistically different at the 95% confidence level

- 1 There are statistically significant differences between the Ford Tempo and the Datsun for the mass emission rate of this species at the 95% confidence level
- 2 There are statistically significant differences between the Ford Tempo and the Ford Mustang for the mass emission rate of this species at the 95% confidence level
- 3 There are statistically significant differences between the Datsun and the Ford Mustang for the mass emission rate of this species at the 95% confidence level

Table F-2. Statistical Summary of Differences in Ion and Element Emissions for Different Vehicles

	Ford Tempo (mg/mi)	Datsun 310 (mg/mi)	Ford Mustang (mg/mi)	P-Value	Pairwise Differences	Ford Tempo	Datsun 310	Ford Mustang	P-Value	Pairwise Differences
(SO ₄) ²⁻	0.0670	0.5117	0.0598	0.1945		3.5%	3.4%	0.2%	0.1446	
NH ₄ ⁺	0.0739	0.2662	0.0691	0.2176		3.7%	2.1%	0.3%	0.1684	
Na	-0.0040	0.0060	0.0476	<u>0.0400</u>	2,3	-0.2%	0.1%	0.3%	0.0825	
Mg	0.0050	0.0109	0.0244	<u>0.0122</u>	2,3	0.3%	0.1%	0.1%	0.1378	
Si	0.1311	0.9281	0.1779	<u>0.0086</u>	1	5.4%	7.4%	0.5%	0.0194	2,3
P	0.0054	0.0108	0.0258	<u>0.0207</u>	2,3	0.3%	0.1%	0.1%	<u>0.0433</u>	2
S	0.0220	0.3679	0.0445	0.1674		1.1%	2.6%	0.1%	<u>0.0457</u>	3
Cl	0.0090	0.0048	0.0058	0.4849		0.4%	0.1%	0.0%	<u>0.0006</u>	1,2
Ca	0.0069	0.0242	0.0038	<u>0.0030</u>	1,3	0.4%	0.3%	0.0%	<u>0.0157</u>	2,3
Fe	0.0156	0.0531	0.0371	0.1144	1	0.8%	0.5%	0.2%	<u>0.0007</u>	1,2,3
Cu	0.0046	0.0009	0.0018	<u>0.0003</u>	1,2	0.2%	0.0%	0.0%	<u>0.0005</u>	1,2
Zn	0.0074	0.0138	0.0103	0.4146		0.4%	0.1%	0.0%	<u>0.0001</u>	1,2,3
Br	0.0004	0.0009	0.0003	0.3940		0.0%	0.0%	0.0%	0.0189	2
Mo	0.0007	0.0241	0.0002	<u>0.0032</u>	1,3	0.0%	0.3%	0.0%	<u>0.0003</u>	1,3
Pb	0.0007	0.0314	0.0023	<u>0.0001</u>	1,3	0.0%	0.3%	0.0%	<u>0.0003</u>	1,3
All Elements and Ions	0.3391	2.0928	0.5219	0.1210		16.0%	16.3%	2.0%	<u>0.0071</u>	2,3

Underlined P-values indicated that there are statistically significant differences between one or more vehicles for this species at the 95% confidence level.

Pairwise differences indicate which vehicle pairs are statistically different at the 95% confidence level

1. There are statistically significant differences between the Ford Tempo and the Datsun for this ion or element at the 95% confidence level
2. There are statistically significant differences between the Ford Tempo and the Ford Mustang for this ion or element at the 95% confidence level
3. There are statistically significant differences between the Datsun and the Ford Mustang for this ion or element at the 95% confidence level

**Appendix G. Statistical Summary of the Cycle and Fuel Effects of Chemical Composition
for Phase 1**

**Table G-1. Statistical Summary of Fuel and Cycle Effects
on Elemental and Organic Carbon (in % of Total Particulate Carbon)**

Fuel Effects

1990 Ford Tempo

	Pre-1992	RFG	% Difference	P-value
OC%	21.5	35.0	13.5%	0.2539
EC%	78.5	65.0		

1981 Datsun 310

	Pre-1992	RFG	% Difference	P-value
OC%	21.7	50.1	28.4%	<u>0.0329</u>
EC%	78.3	49.9		

1967 Ford Mustang

	Pre-1992	RFG	% Difference	P-value
OC%	72.3	80.1	7.8%	0.4976
EC%	27.7	19.9		

Cycle Effects

1990 Ford Tempo

	FTP	Unified Cycle	% Difference	P-value
OC%	24.3	32.2	7.9%	0.3955
EC%	75.7	67.8		

1981 Datsun 310

	FTP	Unified Cycle	% Difference	P-value
OC%	33.1	38.7	5.6%	0.1636
EC%	66.9	61.3		

1967 Ford Mustang

	FTP	Unified Cycle	% Difference	P-value
OC%	78.5	74.0	-4.5%	0.3316
EC%	21.5	26.0		

Underlined P-values are statistically significant at the 95% confidence level

Table G-2. Statistical Summary of Fuel and Cycle Effects on Mass Emission Rates for Ford Tempo (mg/mi)

<i>Fuel Effects</i>			
	Pre-92	RFG	P-Value
(SO₄)²⁻	0.107	0.027	0.1865
NH₄⁺	0.117	0.030	0.4192
Na	-0.003	-0.005	<u>0.0076</u>
Mg	0.004	0.006	0.5852
Si	0.114	0.148	0.5829
P	0.003	0.007	0.1363
S	0.027	0.017	<u>0.0067</u>
Cl	0.007	0.011	0.5647
Ca	0.008	0.005	0.6015
Fe	0.014	0.017	0.2311
Cu	0.004	0.005	0.6669
Zn	0.007	0.008	0.0843
Br	0.000	0.000	0.6114
Mo	0.001	0.001	0.6206
Pb	0.000	0.001	0.4075
All Elements and Ions	0.399	0.279	0.5593
<i>Cycle Effects</i>			
	FTP	Unified Cycle	P-Value
(SO₄)²⁻	0.077	0.057	0.5452
NH₄⁺	0.087	0.061	0.7643
Na	-0.002	-0.006	<u>0.0028</u>
Mg	0.005	0.005	0.9182
Si	0.036	0.226	0.1465
P	0.004	0.006	0.2644
S	0.019	0.024	<u>0.0127</u>
Cl	0.004	0.014	0.3068
Ca	0.008	0.006	0.7710
Fe	0.013	0.018	0.3998
Cu	0.005	0.005	0.9860
Zn	0.005	0.010	<u>0.0228</u>
Br	0.000	0.001	0.0552
Mo	0.001	0.001	0.9266
Pb	0.000	0.001	0.3459
All Elements and Ions	0.267	0.411	0.6148

Underlined P-values are statistically significant at the 95% confidence level

Bold species are at least twice the analytical uncertainty for this vehicle

Table G-3. Statistical Summary of Fuel and Cycle Effects on Mass Emission Rates for Datsun 310 (mg/mi)

<i>Fuel Effects</i>			
	Pre-92	RFG	P-Value
(SO₄)²⁻	0.301	0.722	0.5255
NH₄⁺	0.175	0.358	0.5457
Na	-0.005	0.017	0.1887
Mg	0.014	0.007	0.4684
Si	0.885	0.971	0.2498
P	0.010	0.011	0.8150
S	0.203	0.533	0.5069
Cl	0.006	0.004	0.3039
Ca	0.025	0.024	0.8108
Fe	0.044	0.063	0.3759
Cu	0.001	0.001	0.3020
Zn	0.014	0.014	0.9149
Br	0.001	0.001	0.4318
Mo	0.025	0.023	0.7702
Pb	0.034	0.029	0.7147
All Elements and Ions	1.639	2.546	0.4637
<i>Cycle Effects</i>			
	FTP	Unified Cycle	P-Value
(SO₄)²⁻	0.058	0.966	0.2967
NH₄⁺	0.068	0.464	0.3126
Na	0.002	0.010	0.4513
Mg	0.006	0.016	0.3681
Si	0.210	1.646	<u>0.0158</u>
P	0.009	0.013	0.4795
S	0.057	0.679	0.3167
Cl	0.003	0.006	0.2672
Ca	0.016	0.033	0.1301
Fe	0.025	0.081	0.1403
Cu	0.000	0.001	0.0645
Zn	0.006	0.021	0.1288
Br	0.000	0.002	0.1651
Mo	0.013	0.036	0.1497
Pb	0.015	0.048	0.1899
All Elements and Ions	0.467	3.719	0.1552

Underlined P-values are statistically significant at the 95% confidence level

Bold species are at least twice the analytical uncertainty for this vehicle

Table G-4. Statistical Summary of Fuel and Cycle Effects on Mass Emission Rates for Ford Mustang (mg/mi)

<i>Fuel Effects</i>			
	Pre-92	RFG	P-Value
(SO₄)²⁻	0.054	0.065	0.5818
NH₄⁺	0.069	0.069	0.9802
Na	0.014	0.081	0.2402
Mg	0.017	0.032	0.2698
Si	0.216	0.140	0.5465
P	0.029	0.023	0.5786
S	0.063	0.026	0.4357
Cl	0.008	0.004	0.2587
Ca	0.005	0.003	0.4133
Fe	0.031	0.043	0.3297
Cu	0.002	0.001	0.4589
Zn	0.011	0.009	0.6242
Br	0.001	0.000	0.4592
Mo	0.000	0.000	0.1215
Pb	0.002	0.003	0.5807
All Elements and Ions	0.515	0.529	0.9525
<i>Cycle Effects</i>			
	FTP	Unified Cycle	P-Value
(SO₄)²⁻	0.033	0.086	0.1633
NH₄⁺	0.044	0.094	0.2273
Na	0.044	0.051	0.8352
Mg	0.021	0.028	0.5180
Si	0.032	0.320	0.1916
P	0.015	0.037	0.2109
S	0.018	0.071	0.3291
Cl	0.002	0.009	0.1524
Ca	0.002	0.006	0.1841
Fe	0.024	0.043	0.1619
Cu	0.001	0.003	0.2110
Zn	0.005	0.015	0.1606
Br	0.000	0.001	0.3452
Mo	0.000	0.000	0.6074
Pb	0.001	0.003	0.2072
All Elements and Ions	0.267	0.777	0.2273

Bold species are at least twice the analytical uncertainty for this vehicle

Appendix H. Statistical Summary of the Bag Effects of Chemical Composition for Phase 1

**Table H-1. Statistical Summary of Effects of Driving Phase
on Elemental and Organic Carbon (in % of Total Particulate Carbon)**

1990 Ford Tempo

FTP				
	Bag 1	Bag 2	Bag3	P-value
OC%	32.7	21.9	16.2	0.3603
EC%	67.3	78.1	83.8	

Unified Cycle				
	Bag 1	Bag 2	Bag3	P-value
	32.9	32.4	24.4	0.6610
	67.1	67.6	75.6	

1981 Datsun 310

FTP				
	Bag 1	Bag 2	Bag3	P-value
OC%	17.6	54.9	47.4	0.2206
EC%	82.4	45.1	52.6	

Unified Cycle				
	Bag 1	Bag 2	Bag3	P-value
	16.5	56.0	13.7	0.1290
	83.5	44.0	86.3	

1967 Ford Mustang

FTP				
	Bag 1	Bag 2	Bag3	P-value
OC%	85.6	76.1	77.5	0.1633
EC%	14.4	23.9	22.5	

Unified Cycle				
	Bag 1	Bag 2	Bag3	P-value
	54.6	75.8	56.4	0.3859
	45.4	24.2	43.6	

Table H-2 Bag Effects on Ion and Element Mass Emission Rates for Ford Tempo (mg/mi)

1990 Ford Tempo

	FTP				Pairwise Differences	Unified Cycle				Pairwise Differences
	Bag 1	Bag 2	Bag3	P-value		Bag 1	Bag 2	Bag3	P-value	
(SO ₄) ²⁻	0.261	0.015	0.059	0.4573		0.031	0.060	0.028	0.5149	
NH ₄ ⁺	0.250	0.032	0.068	0.6023		0.062	0.060	0.068	0.9476	
Na	-0.005	-0.005	0.005	0.571		-0.005	-0.007	0.014	0.1535	
Mg	0.011	0.002	0.006	0.1838		0.018	0.004	0.007	0.1644	
Si	0.032	0.042	0.028	0.2948		0.052	0.252	0.036	<u>0.0170</u>	1,3
P	0.010	0.000	0.005	<u>0.0082</u>	1,2,3	0.015	0.007	0.006	0.0869	
S	0.028	0.016	0.020	0.5191		0.015	0.026	0.011	0.1221	
Cl	0.005	0.004	0.004	0.5912		0.006	0.015	0.003	0.1752	
Ca	0.012	0.004	0.012	0.5205		0.013	0.006	0.006	0.1061	
Fe	0.016	0.010	0.016	<u>0.0253</u>	1,3	0.023	0.019	0.014	0.4561	
Cu	0.005	0.004	0.006	0.1071		0.004	0.005	0.004	0.1251	
Zn	0.013	0.002	0.006	<u>0.0077</u>	1,2	0.016	0.010	0.006	0.1284	
Br	0.000	0.000	0.000	0.6173		0.001	0.001	0.000	0.2261	
Mo	0.001	0.001	0.001	0.3727		0.001	0.001	0.001	0.2432	
Pb	0.000	0.000	0.000	0.7435		0.012	0.001	0.001	0.4348	
All	0.585	0.149	0.253	0.5474		0.304	0.435	0.182	0.1241	
Elements/Ions										

Underlined P-values are statistically significant at the 95% confidence level

Includes only species with values at least twice the analytical uncertainty

1 There are statistically significant differences between bag 1 and bag 2 at the 95% confidence level

2 There are statistically significant differences between bag 1 and bag 3 at the 95% confidence level

3 There are statistically significant differences between bag 2 and bag 3 at the 95% confidence level

Table H-3 Bag Effects on Ion and Element Mass Emission Rates for Datsun (mg/mi)

1981 Datsun 310

	FTP				Pairwise Differences	Unified Cycle				Pairwise Differences
	Bag 1	Bag 2	Bag3	P-value		Bag 1	Bag 2	Bag3	P-value	
(SO ₄) ²⁻	0.129	0.037	0.043	0.6249		0.057	1.093	0.031	0.1309	
NH ₄ ⁺	0.113	0.056	0.058	0.5809		0.089	0.520	0.043	<u>0.1705</u>	
Na	0.000	0.002	0.005	0.8966		0.032	0.009	0.011	0.7681	
Mg	0.015	0.005	0.003	0.2298		0.048	0.015	0.003	<u>0.0450</u>	1,2
Si	0.277	0.239	0.103	0.4636		1.067	1.806	0.046	<u>0.0134</u>	2,3
P	0.020	0.004	0.008	0.1078		0.040	0.011	0.021	0.0547	1
S	0.123	0.041	0.037	0.5804		0.166	0.761	0.017	0.1898	
Cl	0.013	0.000	0.001	0.1206		0.043	0.004	0.001	<u>0.0015</u>	1,2
Ca	0.030	0.010	0.015	<u>0.0062</u>	1,2	0.065	0.032	0.023	<u>0.0123</u>	1,2
Fe	0.048	0.016	0.025	<u>0.0267</u>	1,2	0.093	0.081	0.078	0.9063	
Cu	0.001	0.000	0.000	0.3066		0.001	0.001	0.002	<u>0.0415</u>	1,2
Zn	0.016	0.002	0.006	<u>0.0176</u>	1,2	0.032	0.021	0.012	<u>0.0455</u>	2
Br	0.000	0.000	0.000	0.1179		0.002	0.001	0.000	0.3009	
Mo	0.028	0.007	0.012	<u>0.0142</u>	1,2	0.059	0.036	0.020	<u>0.0241</u>	1,2
Pb	0.042	0.004	0.014	<u>0.0108</u>	1,2	0.093	0.047	0.026	<u>0.0299</u>	1,2
All	0.813	0.417	0.300	0.3100		1.894	4.092	0.344	0.0528	

Elements/Ions

Underlined P-values are statistically significant at the 95% confidence level

Includes only species with values at least twice the analytical uncertainty

1 There are statistically significant differences between bag 1 and bag 2 at the 95% confidence level

2 There are statistically significant differences between bag 1 and bag 3 at the 95% confidence level

3 There are statistically significant differences between bag 2 and bag 3 at the 95% confidence level

Table H-4 Bag Effects on Ion and Element Mass Emission Rates for Ford Mustang (mg/mi)*1967 Ford Mustang*

	FTP				Pairwise Differences	Unified Cycle				Pairwise Differences
	Bag 1	Bag 2	Bag 3	P-value		Bag 1	Bag 2	Bag 3	P-value	
(SO ₄) ²⁻	0.051	0.018	0.048	<u>0.0189</u>	1,3	0.150	0.078	0.148	0.3360	
NH ₄ ⁺	0.039	0.048	0.041	0.7737		0.108	0.089	0.152	0.6778	
Na	-0.007	0.058	0.057	0.5800		0.207	0.026	0.250	0.6592	
Mg	0.027	0.017	0.025	<u>0.8370</u>		0.081	0.020	0.083	0.2047	
Si	0.031	0.034	0.041	0.6147		0.167	0.330	0.312	0.6827	
P	0.024	0.006	0.023	<u>0.0042</u>	1,3	0.061	0.036	0.031	<u>0.0399</u>	1,2
S	0.020	0.011	0.030	0.1330		0.046	0.074	0.058	0.7103	
Cl	0.005	0.000	0.004	0.1604		0.023	0.008	0.017	0.6719	
Ca	0.005	0.000	0.002	0.1719		0.022	0.005	0.006	0.1312	
Fe	0.016	0.029	0.020	0.0829	1	0.029	0.052	0.042	0.3178	
Cu	0.002	0.000	0.001	0.0791		0.005	0.003	0.004	0.7414	
Zn	0.010	0.002	0.007	<u>0.0029</u>	1,2,3	0.029	0.015	0.006	<u>0.0055</u>	1,2,3
Br	0.000	0.000	0.000	0.4648		0.000	0.001	0.000	0.2199	
Mo	0.000	0.000	0.000	<u>0.8168</u>		0.000	0.000	0.002	0.4898	
Pb	0.002	0.001	0.001	0.4743		0.002	0.004	0.001	0.6528	
All	0.243	0.221	0.373	0.6340		1.039	0.733	1.173	0.4656	
Elements/Ions										

Underlined P-values are statistically significant at the 95% confidence level

Includes only species with values at least twice the analytical uncertainty

1 There are statistically significant differences between bag 1 and bag 2 at the 95% confidence level

2 There are statistically significant differences between bag 1 and bag 3 at the 95% confidence level

3 There are statistically significant differences between bag 2 and bag 3 at the 95% confidence level

Appendix I. Results of Replicate Chemical Analysis Tests for Phase 1

Table I-1 Comparison of Chemical Mass Emission Rates for Ford Tempo Replicate Tests (mg/mi)

Cycle	Unified Cycle				
Fuel	RFG				
Test #	H9611008,H9611010,H9611014			H9607035, H9607039, H9607041	
Mass Emission Rate (mg/mi)*	2.96			5.16	
Cl ⁻	0.0227	+/-	0.0110	0.0656	+/- 0.0110
NO ₃ ⁻	0.0013	+/-	0.0069	0.0162	+/- 0.0072
(SO ₄) ²⁻	0.0292	+/-	0.0071	0.0801	+/- 0.0082
NH ₄ ⁺	0.0513	+/-	0.0154	0.2099	+/- 0.0210
OC	0.8081	+/-	0.1003	1.5210	+/- 0.1083
EC	1.1742	+/-	0.0918	1.7955	+/- 0.0874
Na	-0.0055	+/-	0.0069	-0.0072	+/- 0.0137
Mg	0.0078	+/-	0.0018	0.0165	+/- 0.0027
Al	0.0020	+/-	0.0014	0.0003	+/- 0.0039
Si	0.2411	+/-	0.0208	0.6572	+/- 0.0188
P	0.0094	+/-	0.0008	0.0174	+/- 0.0009
S	0.0193	+/-	0.0015	0.0364	+/- 0.0012
Cl	0.0171	+/-	0.0016	0.0374	+/- 0.0015
K	-0.0006	+/-	0.0007	0.0000	+/- 0.0003
Ca	0.0073	+/-	0.0006	0.0133	+/- 0.0006
Tl	0.0002	+/-	0.0031	0.0007	+/- 0.0036
V	0.0001	+/-	0.0013	0.0004	+/- 0.0015
Cr	0.0003	+/-	0.0003	0.0007	+/- 0.0003
Mn	0.0002	+/-	0.0002	0.0003	+/- 0.0002
Fe	0.0214	+/-	0.0015	0.0273	+/- 0.0008
Co	0.0000	+/-	0.0003	0.0000	+/- 0.0005
Ni	0.0003	+/-	0.0001	0.0012	+/- 0.0002
Cu	0.0044	+/-	0.0004	0.0048	+/- 0.0002
Zn	0.0108	+/-	0.0007	0.0308	+/- 0.0009
Ga	0.0000	+/-	0.0003	0.0000	+/- 0.0003
As	0.0000	+/-	0.0005	0.0000	+/- 0.0005
Se	0.0000	+/-	0.0001	0.0000	+/- 0.0002
Br	0.0006	+/-	0.0001	0.0006	+/- 0.0001
Rb	0.0000	+/-	0.0001	0.0000	+/- 0.0002
Sr	0.0001	+/-	0.0001	0.0001	+/- 0.0002
Y	0.0000	+/-	0.0002	0.0000	+/- 0.0002
Zr	0.0002	+/-	0.0002	0.0000	+/- 0.0002
Mo	0.0007	+/-	0.0003	0.0006	+/- 0.0004
Pd	0.0000	+/-	0.0011	0.0000	+/- 0.0013
Ag	-0.0002	+/-	0.0013	-0.0002	+/- 0.0015
Cd	0.0002	+/-	0.0013	-0.0004	+/- 0.0015
In	0.0007	+/-	0.0015	0.0002	+/- 0.0018
Sn	0.0016	+/-	0.0019	0.0010	+/- 0.0023
Sb	0.0014	+/-	0.0021	0.0019	+/- 0.0021
Ba	0.0041	+/-	0.0077	0.0028	+/- 0.0099
La	0.0015	+/-	0.0112	0.0000	+/- 0.0132
Au	0.0000	+/-	0.0005	0.0000	+/- 0.0012
Hg	0.0000	+/-	0.0003	-0.0001	+/- 0.0004
Ti	0.0000	+/-	0.0003	0.0000	+/- 0.0004
Pb	0.0032	+/-	0.0004	0.0017	+/- 0.0004
U	0.0000	+/-	0.0003	0.0000	+/- 0.0004

Note: Bold number indicate values that are at least twice the uncertainty

*Mass Emission Rates represent cumulative values over the entire cycle – unweighted

**Table I-2. Results of Replicate Tests for Elemental and Organic Carbon
(% of Total Particulate Carbon)**

Vehicle	Fuel	Cycle	Bag	Test	%OC	%EC
Ford Tempo	Cal. Phase 2	UC	Cumulative	#1	48.3	51.7
			Weighted	#2	46.4	53.6
			Difference		-1.9	+1.9
Datsun 310	Cal. Phase 2	FTP	Bag 2	#1	64.3	35.7
			Bag 2	#2	61.3	38.7
			Difference		-3.0	+3.0
Datsun 310	Cal. Phase 2	UC	Bag 2	#1	68.3	31.7
			Bag 2	#2	48.2	51.8
			Difference		-21.1	+21.1
Ford Mustang	Pre-1992	UC	Bag 2	#1	70.0	30.0
			Bag 2	#2	67.7	32.3
			Difference		-2.3	+2.3

Appendix J. Particulate and Gaseous Emission Results for Phase 2

Appendix J. Particulate and Gaseous Emission Results for Phase 2

Date	Bag 1						Bag 2						Bag 3						
	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi
test # H9801063 1/28/98	2.627	2.318	0.960	69.392	7.26	0.095	0.051	0.228	6.683	1.56	0.318	0.241	0.327	6.063	1.24	0.245	0.184	0.273	9.954
test # H9801066 1/29/98	3.258	2.945	1.055	68.395	0.102	0.069	0.356	9.274	0.35	0.291	0.465	4.991	0.285	0.236	0.401	12.091	0.401	12.091	
test # H9801069 1/30/98	2.377	2.191	1.355	46.775	0.096	0.061	0.306	7.648	0.284	0.233	0.453	4.795	0.228	0.185	0.371	9.5	0.371	9.5	
test # H9801070* 1/30/98																			
test # H9801070* 1/30/98																			
Average	2.754	2.485	1.123	61.521	0.093	0.059	0.288	7.328	1.21	0.317	0.255	0.415	5.283	0.253	0.202	0.348	10.515		
Standard	0.454	0.404	0.206	12.780	0.0113	0.0134	0.0502	1.2078	0.32	0.033	0.031	0.076	0.683	0.029	0.030	0.067	1.384		
Deviation																			
Coeff. of Variation (%)	16.5%	16.2%	18.4%	20.8%															
*replicate Bag 2 test																			

Date	Bag 1						Bag 2						Bag 3						
	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi
test # H9801011 1/7/98	8.512	7.569	1.619	109.463	109.33	0.076	0.058	0.961	3.266	3.90	0.258	0.205	1.248	4.085	2.59	0.529	0.460	1.015	8.864
test # H9801017 1/8/98	8.778	7.887	1.845	106.659	0.077	0.06	0.972	3.44	0.262	0.214	1.339	4.644	0.545	0.481	1.043	8.926			
test # H9801019 1/9/98	6.392	5.682	2.136	84.907	0.07	0.051	0.994	3.06	0.232	0.184	1.258	3.192	0.412	0.354	1.072	7.343			
test # H9801020* 1/9/98																			
test # H9801020* 1/9/98																			
Average	7.89	7.05	1.87	100.34	0.067	0.050	0.94	3.09	0.337	0.25	0.20	1.28	3.97	0.50	0.43	1.04	8.38		
Standard	1.31	1.19	0.26	13.44	0.012	0.010	0.06	0.32	0.51	0.02	0.02	0.05	0.73	0.07	0.07	0.03	0.90		
Deviation																			
Coeff. of Variation (%)	16.6%	16.9%	13.9%	13.4%															
*replicate Bag 2 test																			

Appendix J. Particulate and Gaseous Emission Results for Phase 2

1992 Honda Civic	Date	Bag 1			Bag 2			Bag 3			Weighted						
		THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	
test # H9801060	1/27/98	2.166	2.138	2.445	10.252	6.25	0.179	0.164	0.649	5.58	0.83	0.312	0.272	1.017	6.541	1.5	
test # H9801062	1/28/98	1.896	1.795	2.031	10.177	0.126	0.119	0.629	4.237	0.269	0.239	0.835	4.237	0.228	0.215	0.716	
test # H9801064	1/29/98	2.062	1.943	1.988	13.601	0.115	0.088	0.628	4.468	0.305	0.256	0.838	4.121	0.229	0.197	0.714	
test # H9801065*	1/29/98					0.15	0.117	0.589	6.013	0.31						4.568	
test # H9801065*	1/29/98					0.112	0.083	0.557	5.446	0.27						4.921	
Average		2.041	1.959	2.155	11.343	0.136	0.114	0.610	5.149	0.47	0.295	0.256	0.897	4.966	0.250	0.229	0.733
Standard		0.136	0.172	0.252	1.956	0.0281	0.0323	0.0369	0.7609	0.31	0.023	0.017	0.104	1.365	0.037	0.041	0.031
Deviation																0.685	
Coeff. of Variation (%)		6.7%	8.8%	11.7%	17.2%		20.6%	28.3%	6.1%	14.8%	66.5%	7.8%	6.5%	11.6%	27.5%		
*replicate Bag 2 test																14.7% 17.8% 4.2% 13.4%	

1992 Toyota Corolla	Date	Bag 1			Bag 2			Bag 3			Weighted						
		THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	
test # H9801006	1/6/98	3.315	3.135	1.65	29.725	8.3	0.079	0.067	0.274	2.29	0.96	0.233	0.192	0.472	1.842	2.17	
test # H9801010	1/7/98	2.638	2.499	1.559	34.612	0.124	0.107	0.293	3.393	0.227	0.191	0.574	1.335	0.262	0.237	0.378	
test # H9801016	1/8/98	3.094	2.926	1.583	37.052	0.089	0.076	0.28	2.604	0.191	0.156	0.549	1.438	0.253	0.23	0.367	
test # H9801015*	1/8/98					0.082	0.068	0.291	2.336	0.31				0.258	0.235	3.688	
test # H9801015*	1/8/98					0.065	0.055	0.275	1.995	0.78				0.262	0.237	4.873	
Average		3.02	2.85	1.60	33.80	0.088	0.075	0.28	2.52	0.68	0.22	0.18	0.53	1.54	0.26	0.23	4.29
Standard		0.35	0.32	0.05	3.73	0.022	0.020	0.01	0.53	0.34	0.02	0.05	0.27	0.00	0.00	0.01	0.59
Deviation																	
Coeff. of Variation (%)		11.4%	11.4%	3.0%	11.0%		25.1%	26.3%	3.2%	21.1%	49.1%	10.5%	11.4%	10.0%	17.4%		
*replicate Bag 2 test																1.8% 1.5% 2.6% 13.8%	

Appendix J. Particulate and Gaseous Emission Results for Phase 2

1990 Ford Tempo	Date	Bag 1			Bag 2			Bag 3			Weighted										
		THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi					
test # H9802010	2/4/98	2.639	2.426	3.198	44.072	1.53	0.286	0.229	1.021	9.589	3.53	0.283	0.845	5.045	0.46	0.414	0.348	1.123	11.081	3.21	
test # H9802012	2/5/98	2.742	2.543	2.620	45.429	0.205	0.156	1.159	7.996	0.396	0.363	0.722	4.962	0.351	0.295	1.205	9.747				
test # H9802014	2/6/98	2.637	2.471	3.040	41.026	0.187	0.142	1.138	8.036	0.404	0.320	0.691	6.270	0.331	0.277	1.207	9.648				
test # H9802015*	2/6/98					0.095	0.061	0.58	3.956	2.60											
test # H9802015*	2/6/98					0.074	0.053	0.542	4.360	2.22											
Average		2.673	2.480	2.953	43.509	0.169	0.128	0.888	6.787	2.78	0.385	0.322	0.753	5.426	0.365	0.307	1.178	10.159			
Standard		0.060	0.059	0.299	2.255	0.086	0.073	0.303	2.489	0.68	0.026	0.040	0.081	0.732	0.043	0.037	0.048	0.800			
Deviation																					
Coeff. of Variation		2.2%	2.4%	10.1%	5.2%																
(%)																					
*replicate Bag 2 test																					
1990 Nissan Stanza		Bag 1			Bag 2			Bag 3			Weighted										
		THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi					
test # H9801044	1/21/98	4.513	4.191	2.323	82.433	25.7	0.263	0.224	0.629	12.348	4.65	0.194	0.135	1.214	3.99	1.39	0.482	0.426	0.759	15.452	5.52
test # H9801047	1/22/98	4.669	4.322	2.063	88.202	0.174	0.148	0.705	8.965	0.151	0.091	1.336	2.769	0.408	0.362	0.82	12.682				
test # H9801050	1/23/98	4.265	3.944	1.930	87.081	0.171	0.138	0.596	11.094	0.136	0.074	1.203	4.155	0.382	0.333	0.708	14.581				
test # H9801051*	1/23/98					0.153	0.128	0.738	9.239	2.5											
test # H9801051*	1/23/98					0.08	0.06	0.754	5.086	2.18											
Average		4.482	4.152	2.105	85.905	0.168	0.140	0.684	9.346	3.11	0.160	0.100	1.251	3.638	0.424	0.374	0.762	14.238			
Standard		0.204	0.192	0.200	3.059	0.0653	0.0585	0.0690	2.7555	1.34	0.030	0.031	0.074	0.757	0.052	0.048	0.056	1.416			
Deviation																					
Coeff. of Variation		4.5%	4.6%	9.5%	3.6%																
(%)																					
*replicate Bag 2 test																					

Appendix J. Particulate and Gaseous Emission Results for Phase 2

1989 Toyota Celica	Date	Bag 1						Bag 2						Bag 3						Weighted		
		THC g/mi	NMHC g/mi	NOx g/mi	CO mg/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts.	
test # H9803007	3/3/98	2.417	2.288	2.09	27.848	4.53	0.071	0.049	0.436	4.593	1.35	0.127	0.095	0.398	1.929	0.57	0.197	0.17	0.519	5.623	1.46	
test # H9803009	3/4/98	1.88	1.779	2.129	24.118	0.075	0.054	0.402	5.14	0.137	0.104	0.303	2.131	0.174	0.147	0.485	5.923					
test # H9803011	3/5/98	1.866	1.752	2.202	23.119	0.068	0.044	0.410	5.355	0.146	0.107	0.426	2.249	0.167	0.137	0.504	6.066					
test # H9803012*	3/5/98					0.080	0.057	0.556	5.552	0.64												
test # H9803012*	3/5/98					0.085	0.058	0.471	7.778	1.04												
Average		2.054	1.940	2.140	25.028	0.076	0.052	0.455	5.684	1.01	0.137	0.102	0.376	2.103	0.179	0.151	0.503	5.871				
Standard Deviation		0.314	0.302	0.057	2.492	0.007	0.006	0.063	1.224	0.36	0.010	0.006	0.064	0.162	0.016	0.017	0.017	0.226				
Coeff. of Variation (%)		15.3%	15.6%	2.7%	10.0%		9.0%	11.2%	13.7%	21.5%	35.2%	7.0%	6.1%	17.2%	7.7%		8.8%	11.2%	3.4%	3.9%		
*replicate Bag 2 test																						

1988 Ford Taurus	Date	Bag 1						Bag 2						Bag 3						Weighted			
		THC g/mi	NMHC g/mi	NOx g/mi	CO mg/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts.	CO	NOx
test # H9802055	2/25/98	12.323	11.243	1.503	113.681	61.49	1.836	1.636	0.983	42.544	17.82	3.401	3.092	1.461	35.583	6.57	2.482	2.23	1.043	45.713	19.31		
test # H9802056	2/26/98	8.102	7.422	1.454	91.95	1.922	1.715	0.969	44.37	2.742	2.473	1.472	34.603	2.3	2.064	1.029	46.172						
test # H9802058	2/27/98	11.357	10.349	1.422	110.347	1.907	1.7	0.989	45.483	2.288	2.090	1.543	26.671		2.426	2.178	1.05	47.561					
test # H9802059*	2/27/98					1.594	1.417	1.059	34.887	11.81													
test # H9802059*	2/27/98					1.531	1.363	1.053	32.261	12.81													
Average		10.594	9.671	1.460	105.326	1.758	1.566	1.011	39.909	14.15	2.810	2.552	1.492	32.286	2.403	2.157	1.041	46.482					
Standard Deviation		2.212	1.999	0.041	11.703	0.183	0.165	0.042	5.950	3.22	0.560	0.506	0.045	4.887	0.093	0.085	0.011	0.962					
Coeff. of Variation (%)		20.9%	20.7%	2.8%	11.1%		10.4%	10.5%	4.2%	14.9%	22.8%	19.9%	19.8%	3.0%	15.1%		3.9%	3.9%	1.0%	2.1%			
*replicate Bag 2 test																							

Appendix J. Particulate and Gaseous Emission Results for Phase 2

1987 Buick Park Avenue												1987 Acura Integra													
Date	Bag 1						Bag 2						Bag 3						Weighted						
	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	
test # H9802039 2/18/98	4.476	4.273	4.818	41.027	10.04	0.104	0.077	1.379	1.762	2.77	0.462	0.393	1.647	1.739	1.32	0.359	0.319	1.579	3.822	3.05					
test # H9802041 2/19/98	3.745	3.516	4.456	37.907		0.092	0.059	1.491	0.996		0.493	0.416	1.555	1.203		0.311	0.264	1.651	2.941						
test # H9802043 2/20/98	3.686	3.48	4.804	35.276		0.103	0.069	1.560	1.875		0.496	0.424	2.007	1.527		0.318	0.272	1.76	3.597						
test # H9802046* 2/20/98								0.088	0.055		1.555	1.162	2.79												
test # H9802046* 2/20/98								0.081	0.05		1.338	1.433	2.67												
Average	3.969	3.756	4.693	38.070		0.094	0.062	1.465	1.446		2.74	0.484	0.411	1.736	1.490		0.329	0.285	1.663	3.453					
Standard Deviation	0.440	0.448	0.205	2.879		0.010	0.011	0.102	0.377		0.06	0.019	0.016	0.239	0.270		0.026	0.030	0.091	0.458					
Coeff. of Variation (%)	11.1%	11.9%	4.4%	7.6%		10.5%	17.6%	6.9%	26.0%		2.3%	3.9%	3.9%	13.8%	18.1%		7.9%	10.4%	5.5%	13.3%					
*replicate Bag 2 test																									
1987 Acura												Integra													
Date	Bag 1						Bag 2						Bag 3						Weighted						
	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	
test # H9802025 2/11/98	7.601	6.946	1.074	116.630	9.87	0.667	0.568	0.277	12.840	4.15	1.873	1.714	0.466	18.716	1.87	1.112	0.98	0.332	18.639	4.29					
test # H9802029 2/12/98	8.345	7.613	0.909	123.461		0.759	0.646	0.317	14.212		2.355	2.133	0.425	22.446		1.266	1.114	0.356	20.493						
test # H9802032 2/13/98	8.861	7.97	0.889	136.180		0.817	0.698	0.300	13.957		2.220	2.083	0.543	20.420		1.333	1.172	0.347	20.766						
test # H9802033* 2/13/98								0.810	0.688		0.296	14.602	4.15												
test # H9802033* 2/13/98								0.723	0.605		0.323	13.752	4.24												
Average	8.269	7.510	0.957	125.424		0.755	0.641	0.303	13.873	4.18	2.149	1.977	0.478	20.527		1.237	1.089	0.345	19.973						
Standard Deviation	0.633	0.520	0.102	9.922		0.063	0.055	0.018	0.659	0.05	0.249	0.229	0.060	1.867		0.113	0.098	0.012	1.146						
Coeff. of Variation (%)	7.7%	6.9%	10.6%	7.9%		8.3%	8.6%	6.0%	4.7%		1.2%	11.6%	11.6%	12.5%	9.1%		9.2%	9.0%	3.5%	5.7%					
*replicate Bag 2 test																									

Appendix J. Particulate and Gaseous Emission Results for Phase 2

	Date	Bag 1			Bag 2			Bag 3			Weighted		
		THC g/mi	NMHC g/mi	NOx g/mi	CO Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO Parts. mg/mi
test # H9801048	1/22/98	6.226	5.871	3.361	55.309	34.92	0.517	0.399	1.424	11.641	25.20	1.334	1.194
test # H9801052	1/23/98	5.556	5.207	2.929	63.835	0.519	0.398	1.477	11.933	1.448	1.274	1.877	22.029
test # H9801053*	1/23/98					0.509	0.398	1.369	11.173	11.14			
test # H9801053*	1/23/98					0.43	0.325	1.345	8.904	10.62			
Average		5.891	5.539	3.145	59.572	0.494	0.380	1.404	10.913	15.65	1.391	1.234	1.819
Standard		0.474	0.470	0.305	6.029	0.0427	0.0367	0.0590	1.3753	8.27	0.081	0.057	0.083
Deviation										7.537			
Coeff. of Variation		8.0%	8.5%	9.7%	10.1%		8.7%	9.6%	4.2%	12.6%	52.8%	5.8%	4.6%
(%)											0.086	0.731	1.567
*replicate Bag 2 test											0.016	0.020	14.678

	Date	Bag 1			Bag 2			Bag 3			Weighted		
		THC g/mi	NMHC g/mi	NOx g/mi	CO Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO Parts. mg/mi
test # H9802052	2/24/98	14.659	13.174	1.116	199.590	214.41	0.885	0.702	1.944	32.354	15.81	2.464	2.131
test # H9802053	2/25/98	17.649	16.032	1.130	207.951	1.224	0.996	1.659	46.178	2.339	2.016	1.174	84.726
test # H9802054*	2/25/98					2.323	1.975	0.593	101.295	13.80			
test # H9802054*	2/25/98					2.232	1.892	0.584	100.510	11.96			
Average		16.154	14.603	1.123	203.771	1.666	1.391	1.195	70.084	13.86	2.402	2.074	98.85
Standard		2.114	2.021	0.010	5.912	0.770	0.638	0.710	36.032	1.93	0.088	0.081	4.775
Deviation											0.312	0.279	0.158
Coeff. of Variation		13.1%	13.8%	0.9%	2.9%		43.2%	45.9%	59.4%	51.4%	13.9%	3.7%	3.9%
(%)											16.1%	16.9%	9.2%
*replicate Bag 2 test											0.016	0.020	16.7%

Appendix J. Particulate and Gaseous Emission Results for Phase 2

1984 BMW 318 I													1983 Ford LTD															
			Bag 1				Bag 2				Bag 3							Bag 1				Bag 2						
Date	THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.			
g/mi	g/mi	g/mi	g/mi	mg/mi	mg/mi	g/mi	g/mi	g/mi	g/mi	mg/mi	g/mi	g/mi	g/mi	g/mi	mg/mi	g/mi	g/mi	g/mi	g/mi	mg/mi	g/mi	g/mi	g/mi	g/mi	mg/mi	g/mi	mg/mi	
test # H9805011	5/6/98	6.563	6.224	2.217	58.301	61.76	0.213	0.167	1.079	6.097	33.47	0.664	0.557	1.072	6.507	38.47	0.575	0.51	1.138	8.845	35.30							
test # H9805014	5/7/98	5.634	5.281	2.191	62.847		0.325	0.264	1.041	10.853		0.692	0.576	1.151	6.896		0.628	0.548	1.108	13.297								
test # H9805015*	5/7/98						0.243	0.197	1.071	6.374		4.547	56.37															
test # H9805015*	5/7/98						0.236	0.194	1.122																			
Average		6.099	5.753	2.204	60.574		0.254	0.206	1.078	6.968	45.94	0.678	0.567	1.112	6.702		0.602	0.529	1.123	11.071								
Standard		0.657	0.667	0.018	3.215		0.049	0.041	0.033	2.712	11.59	0.020	0.013	0.056	0.275		0.037	0.027	0.021	3.148								
Deviation																												
Coeff of Variation (%)		10.8%	11.6%	0.8%	5.3%		19.2%	20.1%	3.1%	38.9%	25.2%	2.9%	2.4%	5.0%	4.1%		6.2%	5.1%	1.9%	28.4%								
*replicate Bag 2 test																												
*replicate Bag 2 test													*replicate Bag 2 test															

*replicate Bag 2 test

Appendix J. Particulate and Gaseous Emission Results for Phase 2

1983 Ford Fairmont		Bag 1						Bag 2						Bag 3						Weighted		
	Date	THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.	
test # H9803047	3/19/98	5.145	4.74	3.971	67.735	38.165	1.093	0.872	2.007	26.475	22.42	3.511	3.265	2.88	61.772	14.739	1.477	1.244	2.172	31.131	22.70	
test # H9803048	3/20/98	6.236	5.745	3.771	78.663	1.102	0.89	2.172	26.469	3.563	3.313	3.425	64.795	1.55	1.32	2.346	31.977					
test # H9803049*	3/20/98						0.993	0.772	1.942	28.267	14.77											
test # H9803049*	3/20/98						1.07	0.847	2.028	30.829	14.58											
Average		5.691	5.243	3.871	73.199	1.065	0.845	2.037	28.010	17.26	3.537	3.289	3.153	63.284	1.514	1.282	2.259	31.554				
Standard Deviation		0.771	0.711	0.141	7.727	0.050	0.052	0.097	2.061	4.47	0.037	0.034	0.385	2.138	0.052	0.054	0.123	0.598				
Coeff. of Variation (%)		13.6%	13.6%	3.7%	10.6%		4.7%	6.1%	4.8%	7.4%	25.9%	1.0%	1.0%	12.2%	3.4%		3.4%	4.2%	5.4%	1.9%		
<hr/>																						
1975-1980		Bag 1						Bag 2						Bag 3						Weighted		
1980 Chevy Caprice		THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.	THC	NMHC	NOx	CO	Parts.	
test # H9803031	3/13/98	7.6	6.983	1.737	161.787	238.19	2.986	2.729	1.047	87.074	35.60	4.059	3.782	1.639	80.025	36.89	3.306	3.028	1.125	90.524	45.77	
test # H9803032*	3/13/98						2.657	2.441	1.257	74.869	29.27											
test # H9803032*	3/13/98						2.542	2.353	1.192	67.277	18.03											
Average							2.728	2.508	1.165	76.407	27.63	4.059	3.782	1.639	80.025	3.306	3.028	1.125	90.524			
Standard Deviation							0.230	0.197	0.108	9.988	8.90											
Coeff. of Variation (%)							8.4%	7.8%	9.2%	13.1%	32.2%											
*replicate Bag 2 test																						

Appendix J. Particulate and Gaseous Emission Results for Phase 2

1980 Honda Prelude											
Date	THC g/mi	NMHC g/mi	NOx g/mi	CO mg/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. g/mi	THC g/mi
test # H9803014	3/5/98	4.178	3.929	2.681	50.453	30.95	0.394	0.338	2.622	9.178	8.09
test # H9803015*	3/5/98					0.361	0.309	2.754	7.784	5.91	
test # H9803015*	3/5/98	4.178	3.929	2.681	50.453	30.950	0.371	0.318	2.781	8.225	5.99
Average						0.375	0.322	2.719	8.396	6.663	0.611
Standard Deviation						0.017	0.015	0.085	0.712	1.236	
Coeff. of Variation (%)						4.5%	4.6%	3.1%	8.5%	18.6%	

*replicate Bag 2 test

1979 Plymouth Horizon											
Date	THC g/mi	NMHC g/mi	NOx g/mi	CO mg/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. g/mi	THC g/mi
test # H9801031	1/14/98	6.497	5.871	1.039	97.817	75.16	1.11	0.938	1.691	20.674	153.47
test# H9801038	1/20/98	8.736	8.044	1.033	96.988	54.01	1.077	0.913	1.78	22.29	89.65
test# H9801039*	1/20/98					1.242	1.057	2.164	27.041	127.03	
test# H9801039*	1/20/98					1.324	1.128	2.066	31.459	139.65	
Average		7.617	6.958	1.036	97.403	64.59	1.188	1.009	1.925	25.366	127.45
Standard Deviation		1.583	1.537	0.004	0.586	14.955	0.115	0.101	0.226	4.879	27.416
Coeff. of Variation (%)		20.8%	22.1%	0.4%	0.6%	23.2%	9.7%	10.0%	11.7%	19.2%	21.5%

*replicate Bag 2 test

Appendix J. Particulate and Gaseous Emission Results for Phase 2

1979 Datsun 210										1972 Chevy Caprice											
Date					Bag 1					Bag 2					Bag 3					Weighted	
	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	
test # H9803033	3/13/98	3.203	3.052	3.826	18.866	6.53	0.255	0.224	4.386	0.132	7.88	0.713	0.638	3.94	0.501	1.04	0.442	0.403	4.326	1.151	
test # H9803034*	3/13/98						0.245	0.216	4.007	0.326	4.97									7.41	
test # H9803034*	3/13/98						0.208	0.181	4.007	0.120	5.57										
Average		3.203	3.052	3.826	18.866	6.530	0.236	0.207	4.133	0.193	6.14	0.713	0.638	3.940	0.501	1.040	0.442	0.403	4.326	1.151	
Standard Deviation							0.025	0.023	0.219	0.116	1.54									7.410	
Coeff. of Variation (%)							10.5%	11.0%	5.3%	60.0%	25.0%										
*replicate Bag 2 test																					
pre-1975	1972 Chevy Caprice										1972 Chevy Caprice										
	Date	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi	THC g/mi	NMHC g/mi	NOx g/mi	CO g/mi	Parts. mg/mi
test # H9712051	12/19/97	8.003	7.157	3.16	204.902	309.30	1.805	1.63	5.025	55.312	56.10	2.901	2.724	5.153	45.858	21.05	2.208	1.998	4.935	62.537	67.01
test # H9712052*	12/19/97						1.555	1.416	5.112	42.17	24.30										
test # H9712052*	12/19/97						1.417	1.301	5.189	34.763	17.57										
Average		8.003	7.157	3.160	204.902	309.30	1.592	1.449	5.109	44.082	32.657	2.901	2.724	5.153	45.858	21.050	2.208	1.998	4.935	62.537	67.010
Standard Deviation							0.197	0.167	0.082	10.407	20.579										
Coeff. of Variation (%)							12.4%	11.5%	1.6%	23.6%	63.0%										

Appendix K. Comparison of UC Particulate Emissions for Bag 2 Replicate Tests on Individual Vehicles

Vehicle	PM Emissions from initial test(s) (mg/mi)	PM Emissions from replicate tests (mg/mi)	% Difference
1986+			
1996 Toyota Camry	0.50	0.56	11.0%
1995 Ford Mustang	2.87	5.23	82.1%
1994 Dodge Shadow	1.56	1.04	-33.3%
1993 Plymouth Sundance	3.90	3.10	-20.5%
1992 Toyota Corolla	0.96	0.55	-43.2%
1992 Honda Civic	0.83	0.29	-65.1%
1990 Ford Tempo	3.53	2.41	-31.8%
1990 Nissan Sentra	4.65	2.34	-49.7%
1989 Toyota Celica	1.35	0.84	-37.8%
1988 Ford Taurus	17.82	12.31	-30.9%
1987 Buick Park Avenue	2.77	2.73	-1.4%
1987 Acura Integra	4.15	4.20	1.1%
1981-1985			
1985 Olds. Cutlass	4.92	1.68	-66.0%
1985 Cadillac Seville	6.30	3.40	-46.1%
1983 Ford LTD	21.58	11.69	-45.8%
1983 Ford Fairmont	22.42	14.68	-34.5%
1984 Nissan Maxima	25.20	10.88	-56.8%
1984 Mazda 626	15.81	12.88	-18.5%
1984 BMW 318 I	33.47	52.18	55.9%
1975-1980			
1980 Chevy Caprice	35.60	23.65	-33.6%
1980 Honda Prelude	8.09	5.95	-26.5%
1979 Plymouth Horizon	121.56	133.34	9.7%
1979 Datsun 210	7.88	5.27	-33.1%
Pre-1975			
1972 Chevy Caprice	56.10	20.94	-62.7%

Appendix L. UC Gaseous Bag Emissions Results for Phase 2

NMHC		Average g/mi	Median g/mi	Max. g/mi	Min. g/mi
1955-1975	Bag 1	7.157			
	Bag 2	1.449			
	Bag 3	2.724			
1975-1980	Bag 1	5.230	5.443	6.983	3.052
	Bag 2	1.067	0.665	2.729	0.207
	Bag 3	1.979	1.784	3.782	0.565
1981-1985	Bag 1	6.643	5.539	14.603	1.478
	Bag 2	0.816	0.559	2.168	0.165
	Bag 3	1.807	1.384	3.573	0.485
1986+	Bag 1	3.943	2.669	9.671	1.655
	Bag 2	0.640	0.625	1.465	0.118
	Bag 3	0.541	0.228	2.552	0.027

CO		Average g/mi	Median g/mi	Max. g/mi	Min. g/mi
1955-1975	Bag 1	204.902			
	Bag 2	44.082			
	Bag 3	45.858			
1975-1980	Bag 1	82.127	73.928	161.787	18.866
	Bag 2	30.257	16.881	87.074	0.193
	Bag 3	34.430	28.596	80.025	0.501
1981-1985	Bag 1	98.476	70.816	203.771	18.357
	Bag 2	32.152	15.609	81.091	6.968
	Bag 3	37.264	16.700	88.103	6.702
1986+	Bag 1	55.990	40.790	125.424	11.343
	Bag 2	8.174	5.416	39.909	1.100
	Bag 3	6.894	3.806	32.286	0.478

NO _x		Average g/mi	Median g/mi	Max. g/mi	Min. g/mi
1955-1975	Bag 1	3.160			
	Bag 2	5.109			
	Bag 3	5.153			
1975-1980	Bag 1	2.320	2.209	3.826	1.036
	Bag 2	2.456	2.322	4.133	1.047
	Bag 3	2.259	1.995	3.940	1.108
1981-1985	Bag 1	2.050	1.758	3.871	0.542
	Bag 2	1.196	1.195	2.037	0.530
	Bag 3	1.547	1.508	3.153	0.714
1986+	Bag 1	1.936	1.732	4.693	0.957
	Bag 2	0.640	0.625	1.465	0.118
	Bag 3	0.854	0.714	1.736	0.357

Appendix M. Comparison of UC Bag 2 Replicate Tests

NMHC Emissions

Model Year	# of vehicles	Vehicles decreasing by >25% ^a	Average Bag 2 PM Emissions from first test(s)	Average Bag 2 PM Emissions from replicate test(s)	% Difference
1955-1975	1	0	1.630 g/mi	1.359 g/mi	-16.7%
1975-1980	4	0	1.054 g/mi	1.000 g/mi	-5.1%
1981-1985	7	0	0.785 g/mi	0.847 g/mi	+7.8%
1986+	12	4	0.260 g/mi	0.215 g/mi	-17.4%

CO Emissions

Model Year	# of vehicles	Vehicles decreasing by >25% ^a	Average Bag 2 PM Emissions from first test(s)	Average Bag 2 PM Emissions from replicate test(s)	% Difference
1955-1975	1	1	55.312 g/mi	38.467 g/mi	-30.5%
1975-1980	4	0	29.467 g/mi	27.138 g/mi	-7.9%
1981-1985	7	2	29.706 g/mi	34.599 g/mi	+16.5%
1986+	12	2	8.734 g/mi	7.333 g/mi	-16.0%

NO_x Emissions

Model Year	# of vehicles	Vehicles decreasing by >25% ^a	Average Bag 2 PM Emissions from first test(s)	Average Bag 2 PM Emissions from replicate test(s)	% Difference
1955-1975	1	0	5.025 g/mi	5.151 g/mi	+2.5%
1975-1980	4	0	2.448 g/mi	2.529 g/mi	+3.3%
1981-1985	7	1	1.285 g/mi	1.107 g/mi	-13.8%
1986+	12	1	0.655 g/mi	0.618 g/mi	-5.7%

^aNumber of vehicles where the gas-phase emissions for the replicate test were reduced by greater than 25% from the initial test

Appendix N. Chemical Analysis Results for Phase 2

Appendix N. Chemical Mass Emission Rates for Phase 2 Vehicles (mg/mi)

	1994 Dodge Shadow	1990 Nissan Stanza	1990 Ford Tempo	1989 Toyota Celica	1987 Acura Integra
UC weighted PM	1.84 mg/mi	5.52 mg/mi	3.21 mg/mi	1.46 mg/mi	4.29 mg/mi
Organic Carbon	0.33 +/- 0.11	1.13 +/- 0.15	0.48 +/- 0.11	0.09 +/- 0.10	2.20 +/- 0.24
Elemental Carbon	0.40 +/- 0.04	2.55 +/- 0.24	0.27 +/- 0.03	0.43 +/- 0.05	0.92 +/- 0.09
Total Carbon	0.74 +/- 0.14	3.68 +/- 0.37	0.76 +/- 0.14	0.52 +/- 0.12	3.12 +/- 0.32
NO ₃ ⁻	0.01 +/- 0.01	0.00 +/- 0.01	0.01 +/- 0.01	0.01 +/- 0.01	0.00 +/- 0.01
SO ₄ ²⁻	0.02 +/- 0.01	0.04 +/- 0.02	0.09 +/- 0.02	0.07 +/- 0.02	0.04 +/- 0.02
Cl ⁻	-0.01 +/- 0.01	-0.01 +/- 0.01	0.01 +/- 0.01	-0.01 +/- 0.01	0.00 +/- 0.01
NH ₄ ⁺	0.00 +/- 0.01	0.00 +/- 0.01	0.02 +/- 0.02	0.01 +/- 0.01	0.00 +/- 0.01
Na	-0.02 +/- 0.02	-0.03 +/- 0.03	-0.03 +/- 0.02	-0.03 +/- 0.02	-0.03 +/- 0.03
Mg	-0.01 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Al	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.00	0.00 +/- 0.01	0.00 +/- 0.00
Si	0.09 +/- 0.01	0.54 +/- 0.05	0.34 +/- 0.03	0.01 +/- 0.00	0.11 +/- 0.01
P	0.01 +/- 0.00	0.02 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.04 +/- 0.00
S	0.01 +/- 0.00	0.02 +/- 0.00	0.03 +/- 0.00	0.03 +/- 0.00	0.03 +/- 0.00
Cl	0.00 +/- 0.00	0.01 +/- 0.00	0.05 +/- 0.01	0.01 +/- 0.00	0.02 +/- 0.00
K	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Ca	0.02 +/- 0.00	0.03 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00	0.06 +/- 0.01
Ti	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.02	0.00 +/- 0.01
V	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Cr	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Mn	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Fe	0.03 +/- 0.00	0.10 +/- 0.01	0.01 +/- 0.00	0.09 +/- 0.01	0.29 +/- 0.03
Co	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Ni	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Cu	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Zn	0.01 +/- 0.00	0.03 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00	0.07 +/- 0.01
Ga	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
As	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Se	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Br	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Rb	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Sr	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Y	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Zr	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Mo	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Pd	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Ag	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Cd	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
In	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Sn	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Sb	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Ba	0.00 +/- 0.04	0.00 +/- 0.04	0.01 +/- 0.04	0.01 +/- 0.04	0.00 +/- 0.04
La	-0.03 +/- 0.05	-0.03 +/- 0.05	-0.03 +/- 0.05	-0.03 +/- 0.05	-0.03 +/- 0.05
Au	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Hg	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Tl	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Pb	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.01 +/- 0.00
U	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

Appendix N. Chemical Mass Emission Rates for Phase 2 Vehicles (mg/mi)

1987 Buick Park Ave. 1985 Oldsmobile Cutlass 1984 Mazda 626 1980 Honda Prelude 1979 Plymouth Horizon

UC weighted PM	3.05 mg/mi	5.18 mg/mi	25.32 mg/mi	8.92 mg/mi	97.69 mg/mi	
Organic Carbon	0.71	+/- 0.13	2.39	+/- 0.26	18.78 +/- 1.82	4.82 +/- 0.48
Elemental Carbon	1.21	+/- 0.12	0.78	+/- 0.08	7.17 +/- 0.67	1.22 +/- 0.12
Total Carbon	1.92	+/- 0.22	3.17	+/- 0.33	25.95 +/- 2.47	6.05 +/- 0.59
NO ₃ ⁻	0.00	+/- 0.01	0.01	+/- 0.02	0.00 +/- 0.02	0.01 +/- 0.02
SO ₄ ²⁻	0.05	+/- 0.02	0.05	+/- 0.02	0.06 +/- 0.02	0.14 +/- 0.02
Cl ⁻	-0.01	+/- 0.01	0.00	+/- 0.02	0.00 +/- 0.02	0.01 +/- 0.02
NH ₄ ⁺	0.00	+/- 0.01	0.00	+/- 0.02	-0.01 +/- 0.02	0.02 +/- 0.02
Na	-0.03	+/- 0.02	-0.03	+/- 0.04	-0.03 +/- 0.04	-0.03 +/- 0.06
Mg	0.00	+/- 0.01	0.01	+/- 0.01	0.03 +/- 0.01	0.04 +/- 0.01
Al	0.00	+/- 0.01	0.00	+/- 0.01	0.01 +/- 0.00	0.00 +/- 0.01
Si	0.05	+/- 0.01	0.17	+/- 0.02	0.84 +/- 0.08	0.26 +/- 0.02
P	0.01	+/- 0.00	0.04	+/- 0.00	0.04 +/- 0.00	0.09 +/- 0.01
S	0.02	+/- 0.00	0.03	+/- 0.00	0.07 +/- 0.01	0.07 +/- 0.01
Cl	0.01	+/- 0.00	0.02	+/- 0.00	0.03 +/- 0.00	0.02 +/- 0.00
K	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Ca	0.02	+/- 0.00	0.06	+/- 0.01	0.11 +/- 0.01	0.15 +/- 0.01
Ti	0.00	+/- 0.02	0.00	+/- 0.02	0.00 +/- 0.02	0.00 +/- 0.02
V	0.00	+/- 0.01	0.00	+/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Cr	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Mn	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Fe	0.07	+/- 0.01	0.21	+/- 0.02	0.12 +/- 0.01	0.15 +/- 0.01
Co	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Ni	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Cu	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.01 +/- 0.00
Zn	0.02	+/- 0.00	0.08	+/- 0.01	0.07 +/- 0.01	0.15 +/- 0.01
Ga	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
As	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Se	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Br	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Rb	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Sr	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Y	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Zr	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Mo	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Pd	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.01	0.00 +/- 0.01
Ag	0.00	+/- 0.01	0.00	+/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Cd	0.00	+/- 0.01	0.00	+/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
In	0.00	+/- 0.01	0.00	+/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Sn	0.00	+/- 0.01	0.00	+/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Sb	0.00	+/- 0.01	0.00	+/- 0.01	0.00 +/- 0.01	0.00 +/- 0.01
Ba	0.04	+/- 0.04	0.00	+/- 0.04	0.00 +/- 0.04	0.00 +/- 0.04
La	-0.03	+/- 0.05	-0.02	+/- 0.05	-0.03 +/- 0.05	-0.04 +/- 0.06
Au	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.01
Hg	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Tl	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
Pb	0.00	+/- 0.00	0.01	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
U	0.00	+/- 0.00	0.00	+/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

Appendix O. PAH Results for Individual Phase 2 Test Vehicles

Appendix O. Statistics for Unified Cycle PAH Emissions ($\mu\text{g}/\text{mi}$)

	1994 Dodge Shadow 1.84 mg/mi	1990 Nissan Stanza 5.52 mg/mi	1990 Ford Tempo 3.21 mg/mi	1989 Toyota Celica 1.46 mg/mi
Naphthalene	10.2	+/- 11.7	346.8	+/- 38.4
2-Methylnaphthalene	9.8	+/- 2.3	119.4	+/- 12.8
1-Methylnaphthalene	4.4	+/- 1.2	61.2	+/- 6.6
2,6+2,7-Dimethylnaphthalene	0.3	+/- 1.6	26.2	+/- 3.2
1,7+1,3+1,6-Dimethylnaphthalene	0.2	+/- 2.3	36.6	+/- 4.5
2,3+1,4+1,5-Dimethylnaphthalene	0.2	+/- 1.5	11.3	+/- 1.9
1,2-Dimethylnaphthalene	0.1	+/- 0.8	3.9	+/- 1.0
1,8-Dimethylnaphthalene	0.0	+/- 0.7	0.2	+/- 0.7
Biphenyl	0.4	+/- 0.7	11.1	+/- 1.4
2-Methylbiphenyl	-13.6	+/- 13.7	-13.6	+/- 13.7
3-Methylbiphenyl	-5.7	+/- 5.7	-5.7	+/- 5.7
4-Methylbiphenyl	-2.0	+/- 2.0	-2.0	+/- 2.0
A-Trimethylnaphthalene	0.3	+/- 0.2	6.5	+/- 0.7
1-Ethyl-2-methylnaphthalene	-0.1	+/- 0.2	1.2	+/- 0.3
B-Trimethylnaphthalene	-0.3	+/- 0.7	5.2	+/- 1.0
C-Trimethylnaphthalene	-0.4	+/- 0.7	4.9	+/- 0.9
2-Ethyl-1-methylnaphthalene	0.0	+/- 0.1	0.2	+/- 0.1
E-Trimethylnaphthalene	-0.3	+/- 0.3	3.3	+/- 0.6
F-Trimethylnaphthalene	0.3	+/- 0.2	5.1	+/- 0.6
G-Trimethylnaphthalene	0.1	+/- 0.3	2.2	+/- 0.6
H-Trimethylnaphthalene	-0.2	+/- 0.3	0.3	+/- 0.3
1,2,8-Trimethylnaphthalene	-0.1	+/- 0.2	0.5	+/- 0.4
Acenaphthylene	3.8	+/- 1.0	51.0	+/- 6.0
Acenaphthene	0.0	+/- 0.4	1.9	+/- 0.5
Phenanthrene	11.3	+/- 5.2	150.3	+/- 17.1
Fluorene	2.6	+/- 0.7	36.4	+/- 4.1
A-Methylfluorene	-0.7	+/- 1.1	4.9	+/- 1.5
1-Methylfluorene	0.8	+/- 0.4	7.7	+/- 1.3
B-Methylfluorene	0.2	+/- 0.1	2.2	+/- 0.3
C-Methylfluorene	5.4	+/- 2.3	57.7	+/- 8.1
A-Methylphenanthrene	1.2	+/- 1.0	10.3	+/- 2.0
2-Methylphenanthrene	0.9	+/- 1.0	12.2	+/- 1.8
B-Methylphenanthrene	0.3	+/- 0.2	2.3	+/- 0.5
C-Methylphenanthrene	0.0	+/- 0.4	3.3	+/- 0.9
1-Methylphenanthrene	0.5	+/- 0.6	6.5	+/- 1.1
3,6-Dimethylphenanthrene	0.1	+/- 0.3	1.7	+/- 0.5
A-Dimethylphenanthrene	0.0	+/- 0.4	2.0	+/- 0.5
B-Dimethylphenanthrene	0.0	+/- 0.2	0.8	+/- 0.3
C-Dimethylphenanthrene	-0.1	+/- 0.5	2.3	+/- 0.7
1,7-Dimethylphenanthrene	0.0	+/- 0.3	1.5	+/- 0.3
D-Dimethylphenanthrene	0.0	+/- 0.3	0.9	+/- 0.3
E-Dimethylphenanthrene	0.1	+/- 0.2	1.0	+/- 0.3
Anthracene	2.1	+/- 0.9	27.1	+/- 4.2
9-Methylanthracene	0.0	+/- 0.2	0.4	+/- 0.2
Fluoranthene	7.1	+/- 5.8	67.2	+/- 9.5
Pyrene	8.1	+/- 7.2	61.2	+/- 9.8
A-Methylpyrene	0.0	+/- 0.1	0.0	+/- 0.1
B-Methylpyrene	0.5	+/- 0.3	1.6	+/- 0.3
C-Methylpyrene	0.9	+/- 0.6	3.7	+/- 0.7
D-Methylpyrene	0.4	+/- 0.2	1.6	+/- 0.3
E-Methylpyrene	0.3	+/- 0.3	1.3	+/- 0.3
F-Methylpyrene	0.0	+/- 0.2	0.5	+/- 0.2
Retene	0.0	+/- 0.2	0.0	+/- 0.2
Benzonaphthothiophene	0.0	+/- 0.3	0.0	+/- 0.3
Benz(a)anthracene	0.3	+/- 0.4	1.6	+/- 0.5
7-Methylbenz[a]anthracene	0.0	+/- 0.1	0.0	+/- 0.1
Chrysene	0.7	+/- 0.3	2.2	+/- 0.5
Benzo(b+j+k)fluoranthrene	-0.2	+/- 0.3	0.4	+/- 0.3
Benzo(e)pyrene	0.0	+/- 0.1	0.2	+/- 0.1
Benz(a)pyrene	0.0	+/- 0.4	0.1	+/- 0.4
7-Methylbenzo[a]pyrene	0.0	+/- 0.1	0.1	+/- 0.1
Indeno[1,2,3-cd]pyrene	-0.1	+/- 0.4	0.1	+/- 0.4
Dibenz(a,h+ac)anthracene	0.0	+/- 0.5	0.0	+/- 0.5
Benzo(b)chrysene	0.0	+/- 0.3	0.0	+/- 0.3
Benzo(ghi)Perylene	-0.1	+/- 0.4	0.1	+/- 0.4
Coronene	-0.4	+/- 0.5	-0.2	+/- 0.5
Total	63.1		1164.6	
			146.7	
				172.8

Capital Letters in front of PAHs indicate cases where the exact configuration of methyl groups is not known
 2-methylbiphenyl not included in the sum total since all samples were below background levels

Appendix O. Statistics for Unified Cycle PAH Emissions ($\mu\text{g}/\text{mi}$)

	1987 Acura Integra 4.29 mg/mi	1987 Buick Park Ave. 3.05 mg/mi	1985 Oldsmobile Cutlass 5.18 mg/mi	1984 Mazda 626 25.32 mg/mi				
Naphthalene	219.8	+/- 26.1	47.9	+/- 12.8	241.5	+/- 28.1	3094.0	+/- 323.3
2-Methylnaphthalene	82.9	+/- 9.0	20.9	+/- 3.0	66.2	+/- 7.3	994.5	+/- 104.5
1-Methylnaphthalene	38.3	+/- 4.2	10.4	+/- 1.5	32.0	+/- 3.6	508.1	+/- 53.7
2,6+2,7-Dimethylnaphthalene	18.8	+/- 2.6	2.5	+/- 1.6	10.7	+/- 2.1	181.1	+/- 19.2
1,7+1,3+1,6-Dimethylnaphthalene	26.1	+/- 3.6	3.6	+/- 2.4	14.8	+/- 3.0	267.1	+/- 28.0
2,3+1,4+1,5-Dimethylnaphthalene	9.7	+/- 1.8	1.4	+/- 1.5	4.8	+/- 2.2	88.6	+/- 9.5
1,2-Dimethylnaphthalene	3.5	+/- 0.9	0.7	+/- 0.9	2.0	+/- 1.3	31.1	+/- 3.8
1,8-Dimethylnaphthalene	0.1	+/- 0.7	0.1	+/- 0.7	0.0	+/- 1.0	0.8	+/- 1.1
Biphenyl	13.3	+/- 1.6	3.1	+/- 0.8	15.7	+/- 1.8	105.9	+/- 11.2
2-Methylbiphenyl	-13.6	+/- 13.7	-13.6	+/- 13.7	-13.6	+/- 13.7	-13.6	+/- 13.7
3-Methylbiphenyl	-5.7	+/- 5.7	-5.7	+/- 5.7	-5.7	+/- 5.7	30.0	+/- 6.5
4-Methylbiphenyl	-2.0	+/- 2.1	-2.0	+/- 2.0	-2.0	+/- 2.1	16.5	+/- 2.8
A-Trimethylnaphthalene	6.4	+/- 0.7	1.6	+/- 0.3	2.7	+/- 0.4	42.8	+/- 4.7
1-Ethyl-2-methylnaphthalene	1.2	+/- 0.2	-0.1	+/- 0.2	0.2	+/- 0.2	11.4	+/- 1.4
B-Trimethylnaphthalene	6.3	+/- 1.1	0.7	+/- 0.7	2.2	+/- 0.8	50.7	+/- 5.9
C-Trimethylnaphthalene	5.9	+/- 1.0	0.6	+/- 0.7	1.8	+/- 0.8	47.1	+/- 5.3
2-Ethyl-1-methylnaphthalene	0.2	+/- 0.1	0.1	+/- 0.1	0.1	+/- 0.2	1.7	+/- 0.6
E-Trimethylnaphthalene	4.0	+/- 0.7	0.2	+/- 0.3	1.0	+/- 0.4	35.7	+/- 4.9
F-Trimethylnaphthalene	6.6	+/- 0.8	1.2	+/- 0.2	2.0	+/- 0.3	41.1	+/- 4.7
G-Trimethylnaphthalene	3.1	+/- 0.8	0.4	+/- 0.3	0.8	+/- 0.4	22.4	+/- 5.1
H-Trimethylnaphthalene	0.5	+/- 0.3	-0.2	+/- 0.3	0.0	+/- 0.3	7.1	+/- 1.0
1,2,8-Trimethylnaphthalene	0.9	+/- 0.5	0.2	+/- 0.3	0.1	+/- 0.3	3.9	+/- 1.9
Acenaphthylene	36.9	+/- 4.4	6.5	+/- 1.2	4.7	+/- 1.4	295.9	+/- 34.6
Acenaphthene	2.3	+/- 0.5	3.3	+/- 0.6	1.9	+/- 0.6	51.2	+/- 5.9
Phenanthere	118.6	+/- 13.9	30.4	+/- 6.1	26.6	+/- 5.8	293.8	+/- 32.2
Fluorene	34.1	+/- 3.8	5.1	+/- 0.9	10.1	+/- 1.3	144.9	+/- 15.9
A-Methylfluorene	8.7	+/- 1.9	0.1	+/- 1.2	1.0	+/- 1.2	27.6	+/- 4.4
1-Methylfluorene	8.7	+/- 1.4	1.6	+/- 0.4	2.0	+/- 0.5	26.2	+/- 4.2
B-Methylfluorene	2.6	+/- 0.4	0.5	+/- 0.2	0.6	+/- 0.2	9.2	+/- 1.3
C-Methylfluorene	97.0	+/- 13.1	19.4	+/- 3.5	30.3	+/- 4.7	166.0	+/- 22.1
A-Methylphenanthrene	10.7	+/- 2.1	2.2	+/- 1.0	1.9	+/- 1.0	44.7	+/- 7.5
2-Methylphenanthrene	12.8	+/- 1.9	2.6	+/- 1.1	2.3	+/- 1.1	46.6	+/- 5.7
B-Methylphenanthrene	2.0	+/- 0.4	0.4	+/- 0.2	0.3	+/- 0.2	17.7	+/- 3.2
C-Methylphenanthrene	2.8	+/- 0.8	0.7	+/- 0.5	0.3	+/- 0.5	16.5	+/- 3.7
1-Methylphenanthrene	5.9	+/- 1.0	1.5	+/- 0.6	0.9	+/- 0.6	26.1	+/- 3.5
3,6-Dimethylphenanthrene	1.7	+/- 0.5	0.4	+/- 0.3	0.1	+/- 0.4	10.4	+/- 1.9
A-Dimethylphenanthrene	2.3	+/- 0.5	0.3	+/- 0.4	0.1	+/- 0.4	14.9	+/- 2.3
B-Dimethylphenanthrene	1.0	+/- 0.3	0.2	+/- 0.2	0.0	+/- 0.3	7.9	+/- 1.1
C-Dimethylphenanthrene	1.6	+/- 0.6	0.1	+/- 0.5	0.1	+/- 0.5	20.5	+/- 3.3
1,7-Dimethylphenanthrene	1.5	+/- 0.3	0.2	+/- 0.3	0.0	+/- 0.3	15.1	+/- 1.8
D-Dimethylphenanthrene	1.0	+/- 0.3	0.1	+/- 0.3	0.0	+/- 0.3	7.4	+/- 1.3
E-Dimethylphenanthrene	1.1	+/- 0.3	0.3	+/- 0.2	0.1	+/- 0.3	9.8	+/- 1.2
Anthracene	25.9	+/- 4.0	4.7	+/- 1.1	4.5	+/- 1.1	84.5	+/- 12.7
9-Methylantracene	0.5	+/- 0.2	0.1	+/- 0.2	0.1	+/- 0.2	2.0	+/- 0.6
Fluoranthene	33.7	+/- 6.9	13.4	+/- 6.0	1.9	+/- 5.7	149.0	+/- 17.4
Pyrene	46.4	+/- 8.8	16.8	+/- 7.4	1.1	+/- 7.2	194.5	+/- 22.0
A-Methylpyrene	0.0	+/- 0.1	0.0	+/- 0.1	0.0	+/- 0.2	0.0	+/- 0.2
B-Methylpyrene	1.6	+/- 0.3	0.6	+/- 0.3	0.3	+/- 0.3	9.6	+/- 1.1
C-Methylpyrene	2.8	+/- 0.7	1.6	+/- 0.6	0.3	+/- 0.6	19.5	+/- 2.2
D-Methylpyrene	1.2	+/- 0.3	0.9	+/- 0.2	0.2	+/- 0.3	10.1	+/- 1.3
E-Methylpyrene	1.2	+/- 0.3	0.4	+/- 0.3	0.1	+/- 0.3	6.9	+/- 0.8
F-Methylpyrene	0.5	+/- 0.2	0.3	+/- 0.2	-0.1	+/- 0.2	4.5	+/- 0.7
Retene	-0.1	+/- 0.2	-0.1	+/- 0.2	-0.1	+/- 0.3	0.1	+/- 0.3
Benzonaphthothiophene	0.1	+/- 0.3	0.1	+/- 0.3	0.1	+/- 0.4	0.2	+/- 0.4
Benz(a)anthracene	0.5	+/- 0.4	0.9	+/- 0.5	0.2	+/- 0.6	5.9	+/- 1.5
7-Methylbenz[a]anthracene	0.0	+/- 0.1	0.0	+/- 0.1	0.0	+/- 0.2	0.1	+/- 0.2
Chrysene	0.6	+/- 0.3	1.2	+/- 0.4	0.4	+/- 0.4	6.7	+/- 1.2
Benzo(b+j+k)fluoranthene	-0.1	+/- 0.3	0.5	+/- 0.3	0.7	+/- 0.4	15.1	+/- 2.5
Benzo(e)pyrene	0.0	+/- 0.1	0.2	+/- 0.2	0.3	+/- 0.2	6.3	+/- 1.2
Benzo(a)pyrene	0.0	+/- 0.4	0.1	+/- 0.4	0.3	+/- 0.6	5.8	+/- 1.1
7-Methylbenzo[a]pyrene	0.0	+/- 0.1	0.0	+/- 0.1	0.0	+/- 0.2	0.4	+/- 0.2
Indeno[1,2,3-cd]pyrene	0.0	+/- 0.4	0.1	+/- 0.4	0.1	+/- 0.5	3.8	+/- 1.1
Dibenz(ah+ac)anthracene	0.0	+/- 0.5	0.0	+/- 0.5	0.0	+/- 0.7	0.2	+/- 0.7
Benzo(b)chrysene	0.0	+/- 0.3	0.0	+/- 0.3	0.0	+/- 0.4	0.2	+/- 0.4
Benzo(ghi)perylene	0.1	+/- 0.5	0.3	+/- 0.5	0.6	+/- 0.7	13.4	+/- 2.2
Coronene	-0.1	+/- 0.5	0.0	+/- 0.5	0.3	+/- 0.5	12.9	+/- 3.4
Total	908.2		205.8		485.5		7385.7	

Capital Letters in front of PAHs indicate cases where the exact configuration of methyl groups is not known
 2-methylbiphenyl not included in the sum total since all samples were below background levels

Appendix O. Statistics for Unified Cycle PAH Emissions ($\mu\text{g}/\text{mi}$)

	1980 Honda Prelude 8.92 mg/mi	1979 Plymouth Horizon 97.69 mg/mi
Naphthalene	564.4	$+/-$ 60.4
2-Methylnaphthalene	200.8	$+/-$ 21.3
1-Methylnaphthalene	106.4	$+/-$ 11.3
2,6+2,7-Dimethylnaphthalene	40.3	$+/-$ 5.0
1,7+1,3+1,6-Dimethylnaphthalene	59.5	$+/-$ 7.2
2,3+1,4+1,5-Dimethylnaphthalene	19.0	$+/-$ 4.6
1,2-Dimethylnaphthalene	7.2	$+/-$ 2.6
1,8-Dimethylnaphthalene	0.1	$+/-$ 2.1
Biphenyl	16.0	$+/-$ 1.9
2-Methylbiphenyl	-13.6	$+/-$ 13.7
3-Methylbiphenyl	1.7	$+/-$ 5.7
4-Methylbiphenyl	1.6	$+/-$ 2.1
A-Trimethylnaphthalene	9.6	$+/-$ 1.1
1-Ethyl-2-methylnaphthalene	2.5	$+/-$ 0.5
B-Trimethylnaphthalene	9.0	$+/-$ 1.3
C-Trimethylnaphthalene	7.9	$+/-$ 1.2
2-Ethyl-1-methylnaphthalene	0.0	$+/-$ 0.4
E-Trimethylnaphthalene	5.3	$+/-$ 0.9
F-Trimethylnaphthalene	6.4	$+/-$ 0.8
G-Trimethylnaphthalene	2.9	$+/-$ 0.9
H-Trimethylnaphthalene	0.8	$+/-$ 0.5
1,2,8-Trimethylnaphthalene	0.9	$+/-$ 0.6
Acenaphthylene	63.2	$+/-$ 7.8
Acenaphthene	5.0	$+/-$ 1.3
Phenanthrene	26.7	$+/-$ 5.9
Fluorene	21.8	$+/-$ 2.6
A-Methylfluorene	4.6	$+/-$ 1.5
1-Methylfluorene	3.5	$+/-$ 0.8
B-Methylfluorene	1.5	$+/-$ 0.5
C-Methylfluorene	25.4	$+/-$ 4.1
A-Methylphenanthrene	3.8	$+/-$ 1.2
2-Methylphenanthrene	4.6	$+/-$ 1.2
B-Methylphenanthrene	1.1	$+/-$ 0.5
C-Methylphenanthrene	1.2	$+/-$ 0.6
1-Methylphenanthrene	2.9	$+/-$ 0.8
3,6-Dimethylphenanthrene	1.1	$+/-$ 0.5
A-Dimethylphenanthrene	1.7	$+/-$ 0.6
B-Dimethylphenanthrene	0.7	$+/-$ 0.4
C-Dimethylphenanthrene	2.0	$+/-$ 0.7
1,7-Dimethylphenanthrene	1.1	$+/-$ 0.5
D-Dimethylphenanthrene	0.7	$+/-$ 0.5
E-Dimethylphenanthrene	1.0	$+/-$ 0.4
Anthracene	6.5	$+/-$ 1.3
9-Methylanthracene	0.4	$+/-$ 0.4
Fluoranthene	18.4	$+/-$ 6.2
Pyrene	28.1	$+/-$ 7.8
A-Methylpyrene	0.0	$+/-$ 0.4
B-Methylpyrene	1.8	$+/-$ 0.5
C-Methylpyrene	3.6	$+/-$ 0.8
D-Methylpyrene	1.6	$+/-$ 0.5
E-Methylpyrene	1.8	$+/-$ 0.5
F-Methylpyrene	0.7	$+/-$ 0.4
Retene	0.1	$+/-$ 0.6
Benzonaphthothiophene	0.4	$+/-$ 0.8
Benz(a)anthracene	1.2	$+/-$ 1.1
7-Methylbenz[a]anthracene	0.3	$+/-$ 0.4
Chrysene	1.9	$+/-$ 0.7
Benzo(b+j+k)fluoranthene	3.8	$+/-$ 1.0
Benzo(e)pyrene	1.5	$+/-$ 0.5
Benzo(a)pyrene	0.9	$+/-$ 1.2
7-Methylbenzo[a]pyrene	0.7	$+/-$ 0.5
Indeno[1,2,3-cd]pyrene	0.8	$+/-$ 1.1
Dibenz(a+ac)anthracene	0.3	$+/-$ 1.5
Benzo(b)chrysene	0.1	$+/-$ 0.8
Benzo(ghi)perylene	1.8	$+/-$ 1.4
Coronene	1.0	$+/-$ 0.7
Total	1313.5	3419.1

Capital Letters in front of PAHs indicate cases where the exact configuration of methyl groups is not known
 2-methylbiphenyl not included in the sum total since all samples were below background levels

Appendix P. MOUDI Size Distribution Results for Phase 2

Test Number(s)	Cycle	Vehicle	<10 µm	<2.5 µm	<1.0 µm
1986+					
H9802040/2042/2044	Unified Cycle	1996 Toyota Camry	98.1%	97.2%	94.3%
H9802045	UC Bag 2 replicate	1996 Toyota Camry	100.0%	100.0%	100.0%
	Ave.		99.1%	98.6%	97.2%
H9802006/2009/2013	Unified Cycle	1995 Ford Mustang	90.0%	81.4%	73.6%
H9712048	UC Bag 2 replicate	1995 Ford Mustang	86.5%	74.4%	62.7%
	Ave.		88.2%	77.9%	68.2%
H9801063/1066/1069	Unified Cycle	1994 Dodge Shadow	100.0%	100.0%	93.0%
H9801070	UC Bag 2 replicate	1994 Dodge Shadow	95.8%	95.8%	91.7%
	Ave.		97.9%	97.9%	92.3%
H9801011/1017/1019	Unified Cycle	1993 Plymouth Sundance	99.2%	98.0%	95.1%
H9801020	UC Bag 2 replicate	1993 Plymouth Sundance	100.0%	96.6%	91.0%
	Ave.		99.6%	97.3%	93.0%
H9801006/1010/1016	Unified Cycle	1992 Toyota Corolla	92.9%	86.2%	80.3%
H9801015	UC Bag 2 replicate	1992 Toyota Corolla	86.4%	81.8%	59.1%
	Ave.		89.6%	84.0%	69.7%
H9801060/1062/1064	Unified Cycle	1992 Honda Civic	93.8%	92.6%	80.2%
H9801065	UC Bag 2 replicate	1992 Honda Civic	100.0%	100.0%	100.0%
	Ave.		96.9%	96.3%	90.1%
H9801044/1047/1050	Unified Cycle	1990 Nissan Stanza	98.5%	94.5%	90.2%
H9801051	UC Bag 2 replicate	1990 Nissan Stanza	100.0%	100.0%	91.1%
	Ave.		99.3%	97.2%	90.6%
H9803007/3009/3011	Unified Cycle	1989 Toyota Celica	93.4%	82.6%	71.1%
H9803012	UC Bag 2 replicate	1989 Toyota Celica	91.3%	78.3%	65.2%
	Ave.		92.3%	80.5%	68.1%
H9802055/2056/2058	Unified Cycle	1988 Ford Taurus	98.8%	94.1%	85.3%
H9802059	UC Bag 2 replicate	1988 Ford Taurus	97.7%	92.1%	84.8%
	Ave.		98.3%	93.1%	85.0%
H9802039/2041/2043	Unified Cycle	1987 Buick Park Ave.	96.1%	88.8%	82.0%
H9802046	UC Bag 2 replicate	1987 Buick Park Ave.	96.3%	96.3%	96.3%
	Ave.		96.2%	92.5%	89.1%
H9802025/2029/2032	Unified Cycle	1987 Acura Integra	96.1%	88.4%	83.5%
H9802033	UC Bag 2 replicate	1987 Acura Integra	100.0%	94.0%	91.7%
	Ave.		98.1%	91.2%	87.6%
	Ave all 86+		96.0%	91.3%	84.6%
1981-1985					
H9802023/2026	Unified Cycle	1985 Oldsmobile Cutlass	96.9%	94.0%	91.1%
H9802027	UC Bag 2 replicate	1985 Oldsmobile Cutlass	88.6%	77.1%	68.6%
	Ave.		92.7%	85.6%	79.8%
H9803022/3023	Unified Cycle	1985 Cadillac Sedan DeVille	83.9%	65.7%	54.1%
H9803024	UC Bag 2 replicate	1985 Cadillac Sedan DeVille	84.8%	67.2%	56.6%
	Ave.		84.4%	66.4%	55.3%
H9801048/1052	Unified Cycle	1984 Nissan Maxima	98.7%	96.7%	94.4%
H9801053	UC Bag 2 replicate	1984 Nissan Maxima	97.4%	95.3%	93.8%
	Ave.		98.0%	96.0%	94.1%

Appendix P. MOUDI Size Distribution Results for Phase 2

Test Number(s)	Cycle	Vehicle	<10 µm	<2.5 µm	<1.0 µm
H9802052/2053	Unified Cycle	1984 Mazda 626	99.3%	98.2%	95.3%
H9802054	UC Bag 2 replicate	1984 Mazda 626	96.3%	93.5%	88.9%
		Ave.	97.8%	95.8%	92.1%
H9805011/5014	Unified Cycle	1984 BMW 318i	99.2%	97.7%	93.6%
H9805015	UC Bag 2 replicate	1984 BMW 318i	99.0%	98.2%	94.6%
		Ave.	99.1%	97.9%	94.1%
H9803041/43	Unified Cycle	1983 Ford LTD	97.0%	87.5%	72.9%
H9803044	UC Bag 2 replicate	1983 Ford LTD	98.9%	90.0%	70.8%
		Ave.	97.9%	88.8%	71.9%
H9803047/48	Unified Cycle	1983 Ford Fairmont	96.9%	93.5%	86.6%
H9803049	UC Bag 2 replicate	1983 Ford Fairmont	99.0%	96.5%	93.2%
		Ave.	98.0%	95.0%	89.9%
		Ave. all 81-85	95.4%	89.4%	82.5%
 1975-1980					
H9803031	Unified Cycle	1980 Chevy Caprice	98.2%	96.4%	94.8%
H9803032	UC Bag 2 replicate	1980 Chevy Caprice	97.9%	95.1%	89.0%
		Ave.	98.1%	95.7%	91.9%
H9801031	Unified Cycle	1979 Plymouth Horizon	98.9%	96.3%	88.4%
H9801038	Unified Cycle	1979 Plymouth Horizon	99.2%	97.1%	93.2%
H9801039	UC Bag 2 replicate	1979 Plymouth Horizon	99.4%	98.0%	94.9%
		Ave.	99.2%	97.1%	92.1%
H9803014	Unified Cycle	1980 Honda Prelude	97.0%	94.2%	87.9%
H9803015	UC Bag 2 replicate	1980 Honda Prelude	94.3%	87.1%	81.3%
		Ave.	95.6%	90.6%	84.6%
H9803033	Unified Cycle	1979 Datsun 310	99.3%	96.4%	92.0%
H9803034	UC Bag 2 replicate	1979 Datsun 310	96.5%	89.4%	81.4%
		Ave.	97.9%	92.9%	86.7%
		Ave. all 75-80	97.7%	94.1%	88.8%
 pre-1975					
H9712051	Unified Cycle	1972 Chevy Caprice	97.7%	88.8%	82.1%
H9712052	UC Bag 2 replicate	1972 Chevy Caprice	94.6%	89.5%	83.0%
			96.1%	89.2%	82.6%